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THE PSYCHOLOGICAL REVIEW

THE STRUCTURE OF THE VISUAL WORLD

I. SPACE-PERCEPTION AND THE PERCEPTION OF WHOLES

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1. INTRODUCTORY REMARKS

This series of papers will present the outlines of a very general theory dealing with some of the major problems of visual perception. In this opening article I am chiefly concerned with the development of a hypothesis regarding the basis of the perception of visual *wholes* or *unities*. I shall also treat, in a preliminary way, the problem of the *localization* of visual impressions. It has been pointed out, especially by Duncker (2), that these two problems are intimately related to one another. The idea of their interrelation is fundamental to the present theory.

Another essential feature of this theory is that it departs from the conventional notion of 'psychophysical parallelism' in its treatment of perceptual processes. According to the conventional view, the properties of perceptual experience are determined by those of sensory excitations in the brain; the phenomenal field is, in some sense, a 'copy' or 'image' of the sensory brain-field. Our theory maintains, on the contrary, that perceptual phenomena have a dynamic or motor basis. Perception depends not upon mere reception but upon action-patterns, or *sensori-motor coordinations*.

This general point of view is not new, as those who are familiar with the writings of Hughlings Jackson, Mach, Münsterberg, Washburn, Holt, Langfeld and Peterson will be

aware. In recent years the notion that visual perception is intimately dependent upon motor processes has been advocated by a number of psychopathologists and neurologists, including Goldstein (5), Gelb (4), Pötzl (11a, 12) and Johannes Stein (15). The motor interpretation of perception has taken on a variety of different forms in the hands of different exponents. The theory to be developed in the present paper has much in common, so far as its basic assumptions are concerned, with the ideas expounded by the Belgian ophthalmologist Nuel (11). Our theory also has certain points of resemblance to the doctrines of Jaensch and his students.

The motor theory of perception, in the sense in which the term is used here, is not to be identified with the theory that the properties of perception are dependent upon the ocular kinesthesis resulting from motor response. Such a conception is, strictly speaking, a sensory rather than a motor theory. Moreover, experimental evidence tends to show that ocular kinesthesis has very questionable importance for visual perception, while the role of motor processes is incontestable.

The first problem to be discussed in this paper is that of visual space-perception. The hypothesis will be suggested that space-perception is ultimately determined by motor orientation-tendencies. The perception of direction is determined by oculomotor impulses of fixation. The perception of depth through binocular disparity is based upon orientation-tendencies of convergence. Space-perception is not dependent upon actual movements of the eyes, nor upon the after-effects or 'memories' of such movements, but upon the central arousal of motor impulses.

The different objects in the field of vision give rise simultaneously to opposing motor impulses, each of which strives to enforce a different orientation of the eyes. The subjective localization of the objects in relation to each other is determined by the differences between the directions of these conflicting orientation-tendencies.[1]

[1] The present paper is primarily concerned with this problem of 'relative localization;' the problem of 'egocentric localization,' or localization of visual objects with respect to the observer's body, will only be briefly touched upon.

In the use of the terms 'relative' and 'egocentric' I am following Hofmann (7).

Two or more simultaneously existing orientation-tendencies may not only differ in direction, but the conflict or rivalry between them may be more or less strong. According to our theory, the degree of rivalry furnishes the basis for another important aspect of perception. It determines whether a given stimulus-pattern shall be perceived as a unitary, coherent *whole* or as an array of disconnected parts. The stronger the rivalry of simultaneous motor impulses, the weaker is the coherence of the phenomenal pattern; and the weaker the rivalry, the stronger the coherence.

A number of the laws and properties of coherent wholes will be analyzed from the point of view of this theory. The interconnection between the phenomena of wholeness or coherence and the phenomena of 'relative localization' will also be discussed.

Many of the ideas presented in this paper were suggested, in the first instance, by the study of a case of abnormal visual perception. They were developed in the effort to find an explanation for certain unusual phenomena (phenomena of figural assimilation) which were difficult to understand in terms of prevailing conceptions. In the present paper, however, the theory will be developed upon an independent basis, and the description and interpretation of these pathological findings will be left to a later essay.

In this later essay, I shall be concerned with those visual effects which exemplify an *assimilation-tendency*, or tendency towards simplification of the visual field. In attempting to account for these phenomena, I shall introduce a new idea: that the sensory and motor processes of vision form an interacting system, in which the sensory can not only influence the motor, but the motor can react upon the sensory. The paper immediately following the present one will be devoted to a review of the evidence supporting this conception of *sensori-motor interaction*, and will serve as a preliminary to our discussion of the assimilation-tendency.

After analyzing the phenomena of assimilation, I shall return finally to the problem of *space-perception*, and present a more complete development of the ideas proposed in this

introductory paper. I shall also work out the application of the theory to some of the chief problems of *movement-perception.*

For this theoretical system as a whole, the advantage may be claimed that it enables one to relate together a large group of phenomena—some of which have, at first sight, no obvious relation to each other—with maximum unity and economy of thought. From the point of view of the psychologist, a grasp of the systematic interrelations of phenomena is more important than an understanding of the precise nature of the underlying physiological mechanisms. However, an effort has been made to give the theory as concrete and definite a form as possible. Whatever elements of truth and falsity it contains are then more likely to be brought into the light.

2. The Perception of Direction

We begin with the assumption that each object in the field of vision gives rise to a motor innervation which tends to orient the fixation-point of the retina upon that object. Every object in the peripheral field strives to change the orientation of the fixation-point in a specific way. An object seen with the fixation-point has no tendency to change the orientation of the eye, but it exerts an influence that tends to keep this orientation constant. We may speak of this influence as a 'tension of stability.' In general, we shall describe all these oculomotor innervations as 'orientation-tendencies' or 'tensions.'

The present theory maintains that these tensions furnish the primitive physiological basis for the visual perception of direction. Each tension strives to orient the center of the fovea upon a definite end-point. It is the *end-point* of the tension that determines the phenomenal direction-value. The *strength* of the tension, on the other hand, is correlated with the insistence or dominance of the object in consciousness, as well as with the likelihood of its arousing an actual eye-movement.

A *single* tension has no localization-value. However a conflict between *two* tensions can furnish the basis for a 'rela-

tive localization' of the corresponding objects. Their relative positions in phenomenal space depend upon the difference between the end-points of the two tensions.

In the case of 'relative localization,' a visual object finds its phenomenal standard of reference in some other visual object. In the case of 'egocentric localization,' an object is perceptually located with respect to a bodily system of reference.

This bodily reference-system, as I shall try to show in a later paper, has a motor basis; it corresponds to the prevailing 'equilibrium' of the body, considered as a motor system. The apparent egocentric position of an object is determined by the way in which its own particular motor tension conflicts with this bodily equilibrium (see section 15 below).

3. The Influence of 'Tonus' on Perception, according to Goldstein

At this point it is worth while to consider some of the direct evidence in favor of the idea that relative localization depends upon motor innervations. The most impressive evidence is to be found in the work of Kurt Goldstein and his collaborators, in the field of abnormal perception. Goldstein speaks of a relationship between perception and 'tonus.' Here the word 'tonus' is used in a very general sense, to denote "those involuntary innervations which guarantee the execution of voluntary movements and the maintenance of voluntarily assumed postures" (**5**).

Goldstein has devoted special attention to patients having disorders of tonus which were produced by injury to the cerebellum or frontal cortex. He has found the motor disturbances to be paralleled, in a very significant fashion, by anomalies of space-perception (visual, auditory and tactual). The visual phenomena displayed by his patient Jac., who had a left cerebellar injury, furnish a good illustration (**5**, **4**). This patient manifested an abnormal 'deviation-tendency' in the left side of the body. If his eyes were closed, and he was commanded to hold his outstretched arms straight in front of him and parallel to each other, the left arm would gradually

deviate outwards and downwards, while the right arm remained in place. Under appropriate conditions, analogous deviations were exhibited by any part of the entire musculature of the left side, including the muscles of the left eye.

If the patient, employing only the left eye, fixated the upper end of an objectively vertical line, the line appeared oblique to him, its lower end seeming to deviate to the left. When he fixated the lower end, the line again looked oblique, but it was now the upper end that apparently deviated to the left. When he fixated the middle, the line appeared bent instead of straight, both the upper and lower ends now showing the leftward deviation. These phenomena were experienced only in monocular vision with the left eye. When Jac. employed his right eye, or both eyes, he perceived the line in the normal manner.

If an outline-drawing of a square was presented, and Jac. fixated one corner with his left eye, the square appeared as a rhombus. Very different kinds of distortion were experienced when different corners were fixated. Such figural distortions depended upon a number of other factors in addition to the position of the fixation-point. Line-figures underwent distortion more easily than did figures of solid color. The latter tended to suffer displacement as wholes rather than change of form. The effects depended upon the apparent rigidity or stability of the objects, and, in the case of 'ambiguous' patterns, upon the particular way in which they were apprehended by the patient.

In all of Goldstein's patients, the phenomenal displacements of visual objects were in the same direction as the motor deviation-tendency. Goldstein is inclined to relate these displacements to the deviation-tendency in the motor apparatus of one eye. There was no detectable real movement of the eye which one could correlate with the displacements. The effects seemed to be based upon motor innervations rather than upon movements.

Goldstein and Riese (**6**) have succeeded in provoking visual phenomena of similar type, though weaker in degree, in normal subjects. In the case of these subjects the in-

vestigators produced a unilateral disorder of tonus by cooling the skin of the neck on one side; and again they found phenomenal displacements paralleling the motor deviation-tendency.

Goldstein (5) and Gelb (4) justly emphasize the significance of these results for the theory of perception. According to Goldstein, every perception begins with an orientation (*Zuwendung*) of the organism towards the stimulus. In the less highly developed organisms, the whole body participates in this orientation by performing actual movements. In adult man, a few dominant motor-organs, especially the head, the eyes, and the preferred hand, play the major role, and even these do not always execute real movements. But there is always an orientation-tendency in the form of a state of tonus appropriate to the stimulation. Such orientation-tendencies have a basic importance for perception, and especially for the perception of space.

Goldstein does not present any detailed theoretical interpretation of the anomalies of visual space-perception which he has discovered. It would seem that some of the phenomena might be readily interpreted in terms of the simple schema outlined in section 2. It is apparent, however, that this schema is insufficient to provide an immediate explanation for all of them.

At any rate, the idea of a direct dependence of relative localization upon motor innervations does not rest upon a purely speculative basis. In attempting to build up a specific theory regarding the nature of this dependence, we shall do best to begin with the simplest possible assumptions, and see how far they carry us.

4. Disparative Depth-perception

By disparative depth-perception one means the perception of depth through binocular disparity. Here I shall only indicate, in a very general way, how the facts of disparative depth-perception seem to fit into the framework of a motor theory. A detailed experimental and theoretical analysis of the problem will be presented elsewhere.

The present theory asserts that the binocular perception of depth, like the perception of direction, has a motor basis. While phenomenal direction is founded upon tensions of fixation, phenomenal depth is founded upon tensions of *convergence.*

Phenomenal depth is often assumed to depend, in some way, upon processes involved in the *fusion* of disparate images. Such an assumption is contradicted by the fact that excellent depth-effects can be obtained with double images. Moreover, there is evidence to indicate that the disparate excitation-patterns retain their distinct individuality at a lower level in the cortical system of vision even though they fuse at the higher level, and that the presence or absence of such fusion is irrelevant to the depth-effect.

There is also evidence to support the idea that *disparity* produces depth only in so far as it serves as a stimulus for convergence-impulses. Here I shall cite only the recent experiments of Simon (14). This writer found that the depth-effect produced by a pair of disparate objects is not guaranteed by their geometrical disparity, but depends upon their ability to stimulate the convergence-mechanism. He found that it is possible to construct patterns which, although disparate, have little or no tendency to provoke convergence-adjustments, and that in this case the depth-effect is vague or absent.

Depth-localization, like directional localization, is primarily *relative* (*cf.* sections 1, 2). According to our motor theory, the phenomenal depth-difference between two objects is determined by the difference between the degrees of convergence which the two conflicting tensions strive to produce.

If this theory is right, depth and direction have a broadly similar basis. Although the remainder of this paper will deal only with the perception of two-dimensional patterns, the principles developed there could equally well be applied (with appropriate modifications) to three-dimensional perception.

5. The Perception of Wholes

So far we have considered the way in which the different parts of our field of vision are localized in phenomenal space.

We have next to consider the important fact that our subjective field does not consist of so many tiny bits, each with its particular localization; it contains coherent units or wholes —domains whose parts seem to 'belong together' in a very characteristic way.

The problem of wholes is intimately related to the problem of space-perception. Visual wholes have a spatial structure. Moreover, the nature of our space-perception itself depends upon the way in which the field is partitioned into wholes (*cf.* section 15).

Fig. 1 gives some examples of visual units or wholes. (*Cf.*

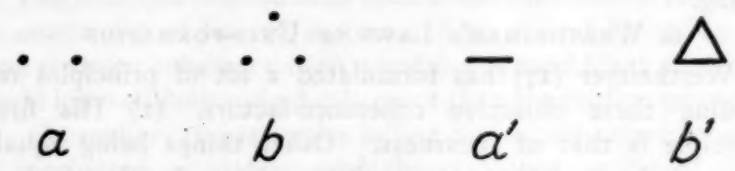

FIG. 1

Koffka, **8**, p. 1221). Such units may have different degrees of internal *coherence*. The reader will probably judge that *a'* and *b'* are more coherent than *a* and *b* and that *b* is more coherent than *a*. In the case of *a* and *b*, the coherence can be strongly influenced by our voluntary attitude, while the coherence of *a'* or *b'* is much more stable and independent of our volition.

Instead of seeing *b* as a triangle, we can, if we wish, perceive it as a dot plus a horizontal line. This represents a partial destruction of the coherence of the original totality. It is difficult, if not impossible, to annihilate the coherence altogether, and experience the pattern as three strictly isolated dots. However, if the separation of the dots were greatly increased, we might achieve this result. If the separation were left unchanged, and the three dots given different colors, their perceptual isolation would be increased, even though it probably would not be complete.

The point-pair *a* is a unit with weak coherence; at first thought, one might hardly be inclined to speak of it as a 'unit' at all. However, there is no abrupt and absolute difference between the case of *b* and that of *a*.

The coherence of *a* would be greatly strengthened if the dots were connected by a straight line, to produce a figure like *a'*. It would be reduced if the dots were farther apart, or if they had different colors. The coherence of the pair moreover depends, in a very pronounced way, upon our deliberate attitude.

It is evident that, in certain cases, we can exercise some degree of arbitrary control over the formation of visual units. In other cases, the coherence seems to be rigidly fixed. There are always certain objective factors promoting or opposing coherence, and the influence of these factors may be weak or strong.

6. Wertheimer's Laws of Unit-formation

Wertheimer (17) has formulated a set of principles regarding these objective coherence-factors. (1) His first principle is that of 'nearness.' Other things being equal, parts of the field that are spatially near each other form a unit. (2) According to the principle of 'similarity,' parts that are like one another in color, or in other respects, have a tendency to appear as a coherent whole. (3) The third principle is that of 'continuation of the curve' (*kurvengerechte Fortsetzung*). If certain parts of the field geometrically describe a straight line, a circular arc, or any sort of curve having a simple internal 'law' of structure, they tend to build a unit. They cohere with each other more strongly than they do with any parts which do not fall in with the 'law.' (4) The fourth principle, that of 'closure' (*Geschlossenheit*), asserts that there is a strong unification-tendency among parts that describe a closed figure. (5) According to the principle of 'the good form' (*die gute Gestalt*), parts tend to become unified in such a way as to produce the most regular figures (from the standpoint of homogeneity of parts, of symmetry about a center, etc.).

It is possible to subsume the last three of Wertheimer's principles under a single principle of *monotonous form*. This principle asserts that those groupings are favored which produce contour lines having a minimum of interruptions, changes in direction, changes in curvature, or, in short,

changes in *formal* character of any kind. Thus, lines or isolated dots readily cohere to produce closed (uninterrupted) figures. Straight lines are 'preferred' to broken or curved lines, and circular arcs have an advantage over lines of varying curvature. A line describing a wavy curve tends to cohere with another such line rather than with a straight line.

Let us then replace Wertheimer's third, fourth, and fifth principles by this single one, and, for certain reasons of convenience, let us add another principle, that of *continuity*. We shall then have the four principles of (1) similarity, (2) continuity, (3) nearness, and (4) monotonous form.[2]

The principle of continuity states that coherence is favored by continuity of line or surface. *E.g.*, *a'* and *b'* in Fig. 1 have stronger coherence than *a* and *b*. A solid black triangle would have still more rigid coherence than the outline-triangle *b'*. (In reality, the examples falling under this principle can be considered as instances of the combined action of the other three factors.)

7. Musatti's Law of Minimum Variations

Now, as a matter of fact, it has been pointed out by Musatti (10) that all of Wertheimer's laws can be reduced to a single law of *minimum variations*. Any factor that introduces variations into the field interferes with coherence; or, conversely, coherence is favored by homogeneity or monotony.

A figure of solid color, for instance, is more coherent than any other kind of figure. If we interrupt the monotony of such a figure, *e.g.*, by introducing color-differences, or by spatially separating the parts from one another, we reduce the coherence. The greater this spatial separation, the weaker the coherence. Moreover, in so far as coherence is influenced by factors of geometrical form, it tends towards least variation—continuity, minimum curvature, minimum change of curvature, and so on.

Suppose that we introduce the term *disjunction* to signify

[2] This particular formulation of the Wertheimer principles is chosen here because it will prove useful at a later point in our theory.

the *opposite* of coherence. A low degree of coherence is equivalent to a high degree of disjunction, and a high degree of coherence is the same thing as a low degree of disjunction.

The law of coherence can then be expressed in either of two ways. We can say that lack of differences promotes coherence, or we can equally well say that *differences promote disjunction.*

8. The Genetic Development of Visual Perception

Having summarized some of the principal facts and laws about visual wholes, we turn next to the question of the theoretical explanation of these facts and laws.

We can put the question in two different ways. We can ask why it is that certain parts of the field cohere to form a whole; or we can ask why it is that certain parts fail to cohere, but remain perceptually disjoined from one another. In other words, we may inquire about the basis of *coherence*, or about the basis of *disjunction.*

As the problem has often been treated, *disjunction* has been regarded as self-explanatory. That is to say, it has been taken for granted that the parts of the field remain phenomenally disjoined unless some positive influence is at work to make them cohere. The only real problem, according to this view, is to explain how this coherence comes about.

Now, perception undergoes a development in the course of individual life. In the type of theory to which we are referring, it has usually been assumed that the visual field has a high degree of disjunction to begin with, and that units or wholes are built up only gradually.

But experimental studies on the perceptions of young children indicate that the initial stages in the growth of perception consist much more in the analysis of already existing wholes than in the formation of new wholes. In general, visual patterns that have a strong coherence for the adult have a much stronger coherence in the perception of the young child (9). The child's vision is 'syncretic' [Claparède (1)] and 'diffuse' [Werner (16)]. The phenomenal world of the child is not an array of discrete elements but consists rather of vague totalities.

Disjunction, then, is not self-explanatory; indeed the primary problem, at the starting-point of a theory of perception, is not to explain coherence but to explain *disjunction.* One may even suggest that, from a certain point of view, coherence is something essentially negative. To paraphrase an expression of William James, everything coheres than *can* cohere, and nothing separates except what must. That is to say, the parts of the visual field always form a coherent unity unless some active influence tears them apart.

This is a basic idea for the hypothesis which is now to be outlined. But before stating this hypothesis, let us refer back to Musatti's principle of minimum variations, and consider how it is to be expressed from our present point of view. This principle now has the following meaning: other factors being equal, visual patterns cohere except where there are sufficient internal contrasts or differences to compel disjunction.

9. The Basis of Coherence and Disjunction

I shall now proceed to formulate a motor theory regarding the basis of coherence and disjunction.

This theory holds that *disjunction is based upon a simultaneous rivalry, or mutual resistance, between oculomotor tensions.* If a visual pattern is to be perceived as an array of disjoined parts, its components must give rise to tensions which strongly oppose one another. The degree of disjunction depends upon the strength of this opposition.

Coherence is, by definition, the contrary of disjunction. Whenever, for any region of the visual field, the total rivalry is weak, that region is experienced as *coherent.* Every part of the field is phenomenally coherent except in so far as there is sufficient rivalry to produce disjunction.

In order to bring out the meaning of 'rivalry,' let us begin with some very simple examples. The most *coherent* of all visual fields is a field which is perfectly *uniform* in color over its whole extent. Now, consider the action of such homogeneous stimulation upon the oculomotor mechanism. There are no details in the field to incite strong orientation-tend-

encies towards particular regions, and to oppose the wandering of fixation into other regions. We can describe the state of affairs by saying that the oculomotor apparatus is placed under a minimum of *constraint*, or that rivalry is at its minimum.

Suppose now that the stimulation is made inhomogeneous; imagine, for example, that a small black figure, let us say a disk or a square, is introduced at some place in the field. At once the field is phenomenally divided into two parts, a 'figure' and a 'ground.' Each of these two regions appears internally coherent, but the two regions appear sharply disjoined from each other. What is the basis for this disjunction of figure from ground?

When the field is made inhomogeneous, its different parts no longer have equal value for the oculomotor system. The black figure introduces a strongly selective orientation-tendency. If the figure is in the peripheral field, it arouses a tension which demands a turning of the eye towards a particular place, and which opposes an orientation of the eye upon other places. Or, if the figure is seen with the fovea, it exerts a 'tension of stability' (section 2) which tends to anchor the eye upon the figure, and to prevent the eye from wandering into the ground-region in any direction.

There is a motor rivalry between figure and ground, in which the figure plays the dominating role. We can say that the figure represents a sharply defined *region of constraint.* Because it produces this selective constraint, the figure is *disjoined*, phenomenally, from the surrounding background.

Figure and background, considered individually, are regions of homogeneous stimulation. There is no rivalry between the various parts of the figure, or the various parts of the ground, comparable to that existing between figure and ground. On this account the field divides itself into two *internally coherent* wholes, a phenomenal figure and a phenomenal ground.

10. The Coherence of Dot-figures

Let us take next a more interesting case, that of a coherent figure built up of spatially separated elements such as dots.

Fig. 1, *a* and *b*, give examples of such patterns. Two facts are to be noted. First, the patterns form coherent units or wholes in spite of the distance separating their elements. Second, the patterns seem to contain invisible *lines* that connect the elements together [*cf.* Koffka (**8**, p. 1221)]. These ghostly connecting-lines become more prominent if we deliberately try to perceive the patterns as wholes. Thus, if the two dots of Fig. 1*a* are seen as a highly coherent pair, they appear to be joined in this way.

Let us examine the case of Fig. 1*a*. Suppose that these two dots, originally isolated, are brought near each other. A change takes place in the relation of each element to its total surroundings. Consider the imaginary lines radiating in all directions from either dot as a center. In all directions except one, the dot contrasts sharply with the surrounding background. But in one direction, that of the line joining the two elements, this contrast is diminished. Neither dot is so sharply set off from its total environment as it would be in the other's absence.

If the two dots were at a large distance apart, each dot would produce a point-like region of constraint. Each would incite motor impulses demanding an orientation of the eye upon one specific end-point, and opposing any other orientation. When the dots are placed near each other, the motor rivalry between them is diminished, because of the diminution in contrast of stimulation.

This pair is set off from its surroundings by strong contrasts on the left and right, as well as above and below. Now, as we have seen, contrasts produce *regions of constraint.* Thus the imaginary line joining the two elements is a region of constraint; the eye is impelled to orient itself upon this *line* rather than upon the surrounding background.

But since neither dot contrasts strongly with its neighbor, there is no longer a very strong tendency for the eye to fixate either dot individually. That is, the region of constraint is not restricted to two points, but spreads over the whole length of the line joining the dots together.

Because of their weakness of rivalry, the dots appear as a

coherent unit or 'pair.' And because their region of constraint includes the whole length of the line between them, the dots give the phenomenal appearance of being *connected together* by an invisible line.

The coherence between two such spatially separated elements is weak as compared with that of a continuous figure. The coherence becomes still weaker if the distance between the elements is increased, since this causes each element to contrast with its total surrounding field in a more decided way, and therefore increases the motor rivalry. The coherence is also reduced if the dots are given different colors, for each dot is again more sharply set off against its total surroundings. The coherence of such a pair is maximum when the two elements are exactly alike.

II. The Objective Conditions of Rivalry

What are the conditions which favor a strong mutual resistance between competing tensions, and which therefore promote disjunction of perceptual patterns? Let us consider first the objective, and later the subjective conditions.

My interpretation of the objective conditions has already been indicated in the previous section. Rivalry, I have suggested, is determined by contrasts or differences between one part of the field and another. In the first place, inhomogeneities in color-stimulation produce rivalry. Gaps or interruptions in a pattern which is otherwise continuous are special instances of color-inhomogeneity. In the second place, a figure composed of spatially separated parts has an internal rivalry which increases with the distance between these parts, since rivalry depends not merely upon the contrast of the elements with their immediate surroundings, but upon the way in which each element stands out from the field as a whole. The greater the spatial separation, the greater this contrast with the total field. In the third place, it may be assumed that contrasting details of geometrical *form* can also incite rivalry. The more monotonous the geometrical structure of a pattern, the less tendency will the eye have to move towards certain particular parts of the figure at the expense of

others. Here again the structure of the pattern as a *whole* will be decisive.

Differences, according to this hypothesis, favor rivalry, and it should follow that differences also favor perceptual disjunction. Or, in other words, it should follow that *homogeneity promotes coherence.* Now, this is exactly the conclusion which we drew (following Musatti) from Wertheimer's laws of coherence. Therefore, if our assumptions are correct, we have arrived at a very simple explanation of those laws.

12. The Subjective Conditions of Rivalry

Coherence and disjunction depend not only upon objective stimulus-differences but upon subjective attitudes and perceptual habits. According to our theory, this means that the degree of rivalry is not solely dependent upon the nature of the stimulus-pattern, but can be influenced by other factors. Within limits, one can deliberately decrease or increase the motor rivalry furnished by a given stimulus-pattern. Rivalry is increased when one assumes a 'totalizing' attitude, and is decreased when one assumes a 'disjunctive' attitude. In course of time the control of rivalry may become habitual and effortless, and the structure of the perceptual field may acquire a permanent change due to learning.

If the present theory is correct, the growth of perception in early life must involve a progressive increase in the strength of simultaneous rivalry, which carries with it an increasing disjunction of the phenomenal field.

Coherence and disjunction can be influenced by a great number of factors; but, according to this theory, all these influences produce their effects by way of the oculomotor system—by modifying the degree of simultaneous rivalry.

13. The 'Totalizing' Fixation-tendency

When the coherence of a figure is strong, there is a weak rivalry between the fixation-impulses due to its individual parts. But it should be pointed out that weakness of *rivalry* does not necessarily presuppose weakness of the fixation-impulses themselves. The impulses may be strong and yet

not manifest any marked tendency to *compete* with one another.

Our theory holds that the essential difference between the motor response in the case of a coherent figure and that in the case of a disjoined figure is not a difference in strength of response but in *form* of response. A figure is coherent when it functions for the motor system as a *whole* rather than as an aggregate of parts. To our first criterion of coherence, namely absence of rivalry, we can add this correlative criterion of the *totalizing response.*

Let us take, for example, the case of a black disk upon a uniform white ground. Now, at the contour of the disk, where black contrasts with white, strong fixation-impulses are aroused. We can regard this contour as made up of small bits, each bit tending to direct fixation upon itself. Thus the oculomotor mechanism is acted upon by a whole system of fixation-tendencies.

However, these fixation-tendencies do not manifest a strong conflict or rivalry with each other. Thus, the eye has relatively little propensity to fluctuate between one part of the contour and another. Now, let us make for the moment an assumption which is not strictly true. Let us assume that there is no rivalry at all between the different contour-elements.

The fixation-tendencies will still continue to act, but they will no longer act as so many sharply individualized impulses. The motor mechanism, instead of being dominated now by this part of the figure, and now by that, will be able to achieve *a steady equipoise under the simultaneous action of all the fixation-tendencies.* The impulses will combine their effects to produce a single *resultant*, somewhat after the fashion of systems of forces in physics.

This resultant fixation-impulse will be directed towards a definite *end-point.* In the case of our black disk, it is easy to see that the motor mechanism will reach a state of balance when the eye fixates the *center* of the disk. This is the end-point of the resultant tension produced by the combined action of all the contour-elements.

Let us next consider another ideal case, that of a figure in which rivalry is *complete*. (Such an ideal figure would have the appearance of a totally *disjoined* aggregate of parts, and would not be a 'figure' at all, in the phenomenal sense.) With such a figure, there would be absolutely no tendency for the elements to act together and produce a single motor resultant.

Now, any actual figure will conform to neither of these two extremes. There will always be a partial, but not a complete *combination* of forces. There will always be a partial, but not a complete *rivalry* between the individual figure-elements acting as separate units. Whether combination or rivalry predominates will vary with the degree of phenomenal coherence possessed by the pattern.

14. The 'Center of Balance' of a Visual Figure

Every simple coherent figure contains a phenomenal 'center of balance' or 'center of gravity.' This phenomenal center can often be easily and immediately identified by the most naive observer, especially when the figure is more or less symmetrical in shape [Rubin (13), Gatti (3)]. In the case of a pair of dots, of a circle, or of an equilateral triangle, for instance, the center of balance coincides with the geometrical center. The center of balance of an isosceles triangle is displaced towards the base of the figure.

According to our theory, this center is a point of *oculomotor balance*. It is the end-point of the *resultant fixation-tendency* furnished by the figure as a whole. The more coherent the figure, the more sharply defined is this phenomenal center (*cf.* section 13).

15. Coherence and Localization

We have next to examine the role which coherence plays in the perception of *spatial relations*. Let us refer to the three objects *A*, *B* and *C* of Fig. 2. *A* and *B*, since they are near together and alike in size, cohere more intimately with each other than with *C*. Now, consider the manner in which *A* and *B* are phenomenally localized. One is primarily con-

scious of the positions of *A* and *B* with respect to each other, rather than of either object's space-relation to *C*. With regard to *C*, the coherent pair is localized as a single whole.

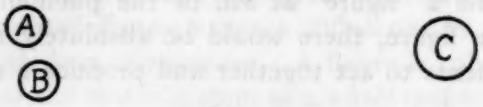

FIG. 2

When two objects are coherent with one another, each furnishes a natural 'frame of reference' for the localization of the other. In the terminology of Duncker (**2**, p. 247), each object has a 'localizedness' (*Lokalisiertheit*) in regard to the other object.

Why is it that the members of a coherent pair tend to have an internal localization, instead of being separately localized with some external object as the standard of reference?

The relative localization of visual objects is determined, according to our assumptions, by a conflict between their oculomotor tensions. Now, when two elements form a coherent pair, the totalizing fixation-tendency (section 13) predominates. The motor impulses tend to combine into a single resultant, directed towards the center of the pair.

From the standpoint of the element *C*, the pair *AB* functions as a unit; it provides a single tension to conflict with the tension of *C*. With respect to *C*, therefore, the pair is localized as a single whole.

If *A* and *B*, as individual elements, are to have any definite localization at all, it can only be a localization with respect to each other. Now, even though *A* and *B* have such strong coherence that their rivalry is of no account from *C*'s standpoint, their coherence will never be perfect. There will always be a slight conflict or rivalry between them; and this conflict will be intense enough, considered as an *internal* conflict, to give the elements an internal localization.

So far we have considered how an object is localized with respect to a second object in the visual field. Let us next inquire into the conditions of *egocentric* localization, or localization with respect to the observer's body.

When two objects are experienced as members of a coherent pair, this pair tends to be egocentrically localized as a whole, rather than as two separate parts; the individual parts tend to be perceived in their relation to each other, rather than in their separate relations to the body. The same thing holds for coherent patterns of a more complicated sort. When coherence is very strong, the parts of the pattern are only vaguely localized with respect to the observer. They are primarily localized with respect to the other parts of the same pattern.

The explanation is much the same as in the purely visual situation of Fig. 2. If an individual figure-element is to be egocentrically localized, it must produce an individual motor tension of its own which enters into conflict with the prevailing bodily equilibrium (section 2). But when a number of elements are united in a coherent whole, they tend to combine their motor effects into a single resultant. Thus, from the body's standpoint, the figure is localized as a whole.

If the pattern-elements are to be sharply localized with respect to the body, the observer must take a *disjunctive attitude*, and increase the rivalry of the elements. The parts will then conflict separately, rather than conjointly, with the bodily equilibrium.

16. Symmetrical and Asymmetrical Coherence

The two dots of Fig. 1*a* have a phenomenal relation to each other which may be called *symmetrical coherence*. The two elements build a whole in which each member plays much the same role. In Fig. 3, however, we have a different situation, which may be described as one of *asymmetrical coherence*. The small dot is experienced as a 'satellite' or 'appendage' of the large disk. One might say that the two objects do not, in the strict sense, *cohere* with each other, but rather that the smaller one *adheres* to the larger.

In terms of our theory, asymmetrical coherence corresponds to an unequal opposition of oculomotor tensions. The disk, because of its size, causes a much stronger tension than the dot. Thus the dot produces only a weak resistance

against the eye's imp fiulse toxate the disk. The disk, on the other hand, offers a strong opposition to the fixation-impulse elicited by the dot. Now, coherence depends upon motor rivalry or conflict. From the point of view of the disk (so to speak), rivalry is feeble; hence the dot 'adheres' to the disk. From the point of view of the dot, rivalry is strong; therefore

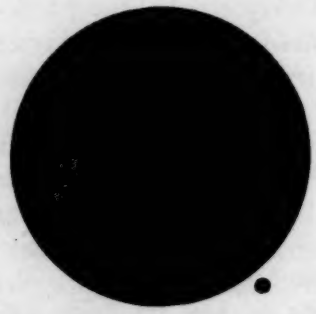

FIG. 3

the disk does not cling to the dot in the same way that the latter clings to the former.

Besides this extreme case of 'adherence,' there are other cases in which the asymmetry is less pronounced. As the inequality of tensions diminishes, we finally reach a case where rivalry is equally strong from the point of view of either element—that is, where coherence is *symmetrical.*

17. SYMMETRICAL AND ASYMMETRICAL LOCALIZATION

In section 15 we saw that coherence favors 'internal' localization. Let us now note that this internal localization may be either symmetrical or asymmetrical. In the case of a pair of objects with symmetrical coherence, relative localization is also symmetrical. Each object, that is, serves as a phenomenal reference-system for the other. But where there is an extreme asymmetry of coherence, the dominant object *A* furnishes a phenomenal reference-system for the subordinate object *B*, but *B* is not the natural reference-system for *A*.

Such a case is illustrated by Fig. 3. When one looks at this figure, one tends to localize the dot in its relation to the

disk; one does not so spontaneously localize the disk with the dot as an object of reference.[3] To use Duncker's expression, the dot has a 'localizedness' in relation to the disk. (The disk, on the other hand, is more naturally localized with respect to some external object on the surrounding page.)

According to the motor theory, relative localization depends upon a conflict of motor tensions. If an object *B* is to be relatively localized, two conditions must be satisfied. First, *B* must give rise to a tension, and, second, this tension must be *opposed* by another tension. That is, there must be another object *A* in the field which produces a tension that is able to *conflict* with the tension of *B*. If this second condition is satisfied, then *A* functions as an object of reference for the localization of *B*.

If two objects are symmetrically coherent, they have equally strong tensions, and each object is localized in terms of the other; that is, their relative localization is symmetrical. But if *A* and *B* are asymmetrically coherent—*A* producing a strong tension, and *B* a weak one—then localization is asymmetrical. As the asymmetry of coherence increases, the localization of *A* becomes less and less dependent upon *B*. In the extreme case, *B* may offer an insignificant opposition to *A*, and therefore have no influence upon the localization of this dominant object. But the stronger tension will exert an important opposition to the weak one. Hence *A* will control the spatial localization of *B*; in other words, *B* will be phenomenally localized in terms of *A* as its reference-standard.

The dominant object *A* tends to be localized on the basis of its conflict with some third visual object of strong tension, or on the basis of its conflict with the egocentric reference-system. That is, *A*'s localization tends to be external rather than internal.

[3] In the same fashion, one perceives a window in its relation to a house, but one does not localize the house in terms of the window as a reference-object. (As Duncker has pointed out, the asymmetry of localization tends to be especially pronounced when a large object *encloses* a small one.)

18. The Relation of the Motor Theory to the Theory of Gestalt

It will be evident to the readers of these papers that the present theory is heavily indebted to the work of the *Gestalt* psychologists Wertheimer, Koffka and Köhler, and their collaborators. It remains to make a few remarks regarding the relation between the two points of view.

Our theory resembles the *Gestalt* theory in its rejection of 'atomistic' interpretations of perception. In our treatment of space-perception, for example, we assumed that localization is always determined by *relations* between motor tensions, rather than by individual tensions. The tensions themselves were in turn said to be conditioned by relations of stimulation —by the total distribution of stimulation with respect to space and color. In discussing the problem of coherent wholes, we did not regard these wholes as functionally equivalent to the sum of their isolated parts, or as derived from such parts by any sort of 'synthesis.' In fact, if our theory is right, wholes are functionally simpler and more primitive than isolated elements. Analysis, or isolation of elements, represents a real achievement rather than a primordial starting-point.

The two theories differ in their point of view regarding the psychophysical relation. The *Gestalt* theory usually has adhered, in principle, to the orthodox psychophysical parallelism, which considers perceptual patterns as 'copies' of sensory brain-patterns. In so far as it postulates that perception is directly dependent upon sensori-motor co-ordinations, the present theory seems to be even more extreme than the *Gestalt* theory in its emphasis upon 'totality.'

19. Summary

This paper offers the outlines of a motor theory regarding visual perception. The main points will be summarized:

1. The relative localization of visual objects is founded upon a conflict between the oculomotor orientation-tendencies or 'tensions' aroused by the objects. The perception of relative direction rests upon tensions of fixation, the binocular perception of relative depth upon tensions of convergence.

2. Two visual objects *A* and *B* are said to be 'symmetrically' localized with respect to one another when each object serves as a phenomenal reference-system for the other. If *A* is phenomenally experienced as a reference-system for *B*, but *B* is not the reference-system for *A*, localization is called 'asymmetrical.' Symmetry or asymmetry of localization depends upon symmetry or asymmetry in the conflict of tension. In asymmetrical localization, the object having the stronger tension functions as a reference-system.

3. The egocentric localization of a visual object depends upon the way in which its own motor tension conflicts with the motor 'equilibrium' of the body.

4. The perception of a visual pattern as a coherent *whole*, or as a disjoined aggregate, is determined by the strength of conflict between the oculomotor tensions produced by the various parts of the pattern. Disjunction corresponds to a strong rivalry of tensions; coherence (lack of disjunction) corresponds to a weak rivalry.

5. Coherence is favored by a number of objective factors, as Wertheimer has shown. The principal objective coherence-factors are similarity, continuity, nearness in space, and monotony of form. As Musatti has pointed out, all these factors can be reduced to the single factor of homogeneity or minimum variations.

The law of minimum variations is explained on the assumption that objective differences tend to provoke rivalry of tensions. Homogeneity, or lack of differences, is unfavorable to rivalry and therefore promotes coherence.

6. Coherence and disjunction also depend upon subjective factors, such as age, attitude and training. It is assumed that all such factors produce their effects by modifying the degree of oculomotor rivalry.

7. As the coherence of a visual pattern becomes strong, the rivalry of fixation-impulses tends to be replaced by a combination of these forces into a single resultant, directed towards the 'center of balance' of the whole.

8. Because of this combination of forces, a coherent pattern tends to be localized as a single whole with respect to

any external system of reference. The individual elements of the pattern do not have any definite phenomenal position with respect to such an external standard; their localization is 'internal' rather than 'external.'

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A THEORY OF *PSYCHOLOGICAL* COMPONENTS—AN ALTERNATIVE TO 'MATHEMATICAL FACTORS'

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It is the possession of concepts, motives, and emotions which differentiates individuals in intellectual and personality characteristics. And it is 'universes' of these psychological determinants which 'tests' attempt to sample. These components are, however, so numerous and complex, the experimental study of their origins in the individual so difficult and laborious, their hereditary and environmental conditions so resistant to scientific analysis that some psychologists have sought various types of flight from reality into simplified, albeit fictitious, postulations of the causal determinants of behavior differences. One type of escape has been in the assumption of the existence of large psychological determinants such as 'general intelligence,' 'introversion-extroversion,' and other 'traits.' Serious students of individual differences reject such alleged determinants; since no attempt is made to describe their psychobiological properties, or the fundamental conditions of their emergence in the individual. Another type of escape has recently presented itself, one considerably more dangerous than 'trait-mongering' because it is more artful. I refer to the recent proposals to accept 'mathematical factors' as the determinants of individual differences. Here the escape has been into mathematics, and though it avoids the real problem in no less a degree than does 'trait-mongering,' it has the semblance of being more scientific by virtue of its mathematical content. The purpose of this paper is first, to show that 'mathematical factors' represent yet another *ignis fatuus*, and second, to present a systematic *psychological* envisagement of the determinants of individual differences.

Arbitrary and Non-psychological Character of 'Mathematical Factors'

The acceptance of 'mental factors' educed by factor analysis [1] from observed intercorrelations between psychological tests entails the belief in the validity of a certain set of assumptions concerning the determinants of individual differences. The general and broad group factors derived from data under these assumptions have no more validity than the assumptions themselves, and unfortunately, these latter are not verified by psychological or genetic experiment. I have therefore termed such factors 'mathematical factors' in order better to differentiate them from factors subject to experimental variation and study.

Before observing the assumptions made by mathematical-factorists, let us symbolize two current factor theories:

G theory	*P theory*
$x_1 = k_1 g + k_2 s_1,$	$x_1 = \alpha_1 a + \beta_1 b + \gamma_1 c + \cdots \delta_1 d,$
$x_2 = k_3 g + k_4 s_2,$	$x_2 = \alpha_2 a + \beta_2 b + \gamma_2 c + \cdots \epsilon_2 e.$

The *G* theory states that individual differences in each of the two abilities x_1 and x_2, are determined by one general factor, *g*, and the specifics. Spearman, its proponent, may admit a few additional non-specific factors. The *P* theory, where *P* stands for parsimony, postulates the smallest number of general or group factors plus specifics leading to consistency.

[1] See the following references on factor analysis:

C. Spearman, The abilities of man, N. Y.: Macmillan, 1927.

T. L. Kelley, Crossroads in the mind of man, Stanford University Press, 1928.

H. Hotelling, Analysis of a complex of statistical variables, *J. Educ. Psychol.*, 1933, 24, 417–444, 498–520.

L. L. Thurstone, The theory of multiple factors, Ann Arbor: Edwards Bros., 1933.

L. L. Thurstone, The vectors of mind, Psychol. Rev., 1934, 41, 1–32.

R. C. Tryon, Multiple factors vs. two-factors as determiners of abilities, Psychol. Rev., 1932, 39, 324–351.

R. C. Tryon, So-called group factors as determiners of abilities, Psychol. Rev., 1932, 39, 403–439.

In the last two references, the writer presented a statistical critique of mathematical factor theories emphasizing especially the two-factor theory. My purpose in those papers was primarily destructive, as I offered little in the way of an alternative to mathematical factors. The present article attempts to construct an alternative theory.

Kelley and Thurstone think of abilities in terms of the *P* theory. Spearman names his general factor, *mental energy*, whereas Kelley would call his set *verbality, number, space, etc.* The assumptions upon which these factor systems are based and without which these factors could not be postulated may be considered under the several heads indicated below.

Number of factors.—Both the *G* and *P* systems assume a very small number of general or group factors, and ordinarily as many specifics as tests. In defense of this assumption, mathematical-factorists generally resort to the rule of parsimony, that is, where a given set of intercorrelations may be described in terms of any one of a large number of mathematical factor patterns (and this is *always* the case) which differ in the number of factors in each, that particular pattern is chosen which contains the fewest factors.

"There is thus an infinite number of ways in which you could represent the ability to produce a performance on [a] test. . . . In dealing with observed relations between variables, one factor problem is to discover the lowest order of complexity that will account for the observed relations . . ." (p. 4). "We want to know the smallest number of factors by which any given table of coefficients can be described" (p. 16). Thurstone, *Theory.*

". . . We will systematically choose the hypothesis involving the lesser number of unknown factors" (p. 69). "Adopting the law of parsimony we will not resort to this system [a factor pattern involving one general and *two* group factors] if systems (49) and (50) suffice" (p. 71). [(49) and (50) are patterns involving one general and *one* group factor.] Kelley, *Crossroads.*

"The fact that any variable can be divided into the two factors, *g* and *s*, does not, of course, preclude it from being divisible in an infinity of other ways" (pp. vi *ff.*). [Spearman chooses the two-factor way because he considers it mathematically a unique solution.] Spearman, *Abilities.*

No one may object to mathematical-factorists employing the rule of parsimony in order to simplify their problem. One must realize, however, that the factors which come out of the analysis are *chosen* from many possible sets, and that the rule of choice is *arbitrary.* Now, it happens that the 'law' of

parsimony is not a natural law, but a rule agreed upon among men to simplify their thinking. With reference to the psychobiological causes of individual differences, nature does not appear, however, to work parsimoniously but rather most prodigally. As will be shown later, the experimental evidence from psychological and genetics laboratories indicates that a very large number of causes determine mental differences. Hence, the employment of the rule of parsimony to select out a parsimonious set of factors would appear to depict a fiction *if* such a depiction is urged as a representation of psychobiological causes.

Interrelation between factors.—Proponents of the *G* and *P* systems assume that factors are *uncorrelated*, at least the mathematical factors they postulate must show zero intercorrelations.

"We shall locate the coördinate axes, *i.e.*, the principal factors so as to maximize the sums of the squares of the projections of the test on the axes. These axes will be orthogonal since the factors are uncorrelated" (p. 17). Thurstone, *Theory*.

With reference to one of his fundamental equations, Kelley says: "The specific factors are e_1 and e_2 [in two tests]. The common factor is *a*. The independent variables *a*, e_1 and e_2 are uncorrelated" (p. 39). Kelley, *Crossroads*.

"First of all, g_x is always the same for the individual *x*, whatever may be the ability under consideration, *a*, *b*, *c*, *etc.* Contrariwise, his s_{ax}, s_{bx}, s_{cx}, vary from one ability to another independently both of each other and of the value g_x" (p. xv). Spearman *Abilities*.

To assume zero intercorrelation is of course formally permissible but, as will be shown later, it is unsound if the factors are presumed to represent psychological components.

Combination of factors.—Another assumption refers to the way mathematical factors are made to combine in producing an individual's total score. A glance at the *G* and *P* equations shows that the score is assumed to consist of the simple algebraic *summation* of his degrees of excellences in the sundry atomistic factors.

"We also make the assumption that the contributions of several

independent factors are summative in the individual's performance on each of the psychological tests" (p. 6). Thurstone, *Vectors*.

Kelley refers to the use of Taylor's Series as the rationale for his expressing any test score as a summation of factors (p. 38). Kelley, *Crossroads*.

"Surprise may be felt that the measurement . . . , even if truly enough a function of the two factors general and specific, should so simply consist of merely the *sum* of these added together. . . . The answer to this question is that our proof has depended upon the usage of Taylor's theorem, according to which all mathematical functions however complex can, in general, be expressed in the above simple additive form with some approximation" (p. xv). Spearman, *Abilities*.

We are here again confronted with another assumption which no doubt is mathematically convenient and symbolically feasible. But in the opinion of many psychologists, especially of the configurational school, an assumption of additive factors would be considered clearly inconsistent with other experimental evidence. Likewise, the geneticist has discovered many instances of multiple genetic factors interacting non-cumulatively. Mathematical factors therefore appear to represent neither psychological nor genetic components.

Weight of factors.—Each mathematical factor possesses a weight in determining the individual's total score. These are the k weights of the G pattern, and the Greek letter weights of the P pattern. The assumption is made that the weight ('saturation' or 'loading') of a given factor in determining each individual's total scores is exactly the same for all individuals, who differ only in their relative ranks in the factor variable.

"The coefficients a_1 and a_2 [weights of two factors in a given test] are essentially properties of the test. . . ." (p. 2). [Thus each is considered constant for all individuals.] Thurstone, *Theory*.

". . . c_1 [weight of a factor] is some constant not changing as we pass from member to member of the group in question" (p. 38). Kelley, *Crossroads*.

"As for the r's [weights of g and s], these vary for the different abilities a, b, c, *etc.*, but, of course, do not vary for the different individuals" (p. xv). Spearman, *Abilities*.

The present writer believes that this new assumption has little validity with reference to factors having psychological significance. He will attempt to show later in this paper that such an assumption certainly does not apply to psychological components.

Nature and origin of factors.—When the mathematical-factorist comes to the final problem of stating the psychological nature and the origin of his factors, he usually confesses that his factor methods do not definitely inform him of these important particulars. As an ancillary procedure, he may pick out those tests which appear to be most heavily weighted by a given factor, note the content of these tests, and label the factor with a verbal abstraction which best defines the common element of the manifest content of the selected tests. This naming procedure is highly subjective. One cannot be sure that another psychologist noting the subject matter of the selected tests might not observe other common elements and give a different name. Even if one is relatively content with the label given, the disconcerting fact often appears that *other* tests in the analysis, though not saturated by the factor in question, may contain subject matter satisfying the same abstract definition.

In 'The vectors of mind,' Thurstone appears to be concerned with two problems: the giving of a psychological label to (1) the principal axes or factors educed by his method and (2) the clusters of tests which are revealed by the objective intercorrelations and graphically indicated by points within or on the surface of an n-dimensional sphere. Regarding (1), Thurstone states that "the location of the axes is arbitrary and *without fundamental psychological significance*" (p. 27, italics mine). But in (2), "we have something more or less permanent in terms of which we may define psychological categories and mental abilities" (p. 27). [Apparently the defining is done by discovering a verbal term best covering the operations involved in the tests of a cluster.]

"It must be understood that the captions [psychological names] . . . describing the general and group factors . . . are merely words giving what the writer surmises to be the nature of the factors." How these surmises are arrived at may be illustrated in Kelley's naming of factor β as a 'verbal' factor. He discovered

that this factor showed heavy positive weights in his Tests 1 and 2, and weights of low value in Tests 3 and 5. No weight was found in Tests 4, 6, 7, 8, or 9. Kelley writes: "The appropriate verbal description of the factor can only be surmised by a study of the nine tests and the selection and naming of the element present in large amounts in Test 1 and 2, in slightly negative amount in Test 3, in slightly positive amount in Test 5, and absent in the remaining five tests. The writer's characterization of this as a 'verbal' factor is the result of such a procedure on his part" (p. 107). Kelley, *Crossroads*.

"Having ascertained which abilities involve *g*, our next step is to find the *degree* that they involve it. . . ." One purpose of this procedure is that of "throwing light on the intrinsic nature of the two factors" (p. 199). "The best means for measuring the amount of *g* in any ability, say *a*, consists simply in the correlation . . . , r_{ga}" (p. 200). In Chapter XII, Spearman examines many types of test content with reference to the weights by which each type is determined by *g*, and in his 'Cardinal Conclusions' summarizes his findings by the statement that "It [*g*] showed itself to be involved invariably and exclusively in all operations of eductive nature, whatever might be the class of relations or the sort of fundaments at issue" (p. 411). Spearman, *Abilities*.

Thus the psychological nature of a mathematical factor is inferential and moot. Further, what is its fundamental origin? To what extent is it genetically and environmentally determined? How may it be investigated experimentally? To these questions, the factorist has yet to provide an answer.

In fairness to mathematical-factorists, it should be said that the more competent ones are fully aware of the nature of the assumptions they employ, but it must also be said that none has clearly listed all of these assumptions and discussed their *psychological* implications. We are here not concerned with the factorists' algebra, but with their assumptions, which, I believe, do not have psychological or biological meaning. It may be that what is needed is more, rather than less, factor analysis. The future may see new methods derived in which such arbitrary restrictions as parsimonious selection, zero intercorrelations, etc., are relaxed. It may ultimately be that mathematical factors will represent descriptions of

psychological or genetic components. To the present writer, however, the future along these lines looks black. The best promise for the study of individual differences lies in other directions.

The Psychological Components of Individual Differences

In view of the artificiality of the assumptions involved in the postulation of mathematical factors and of their amorphous psychological nature and origin, it appears necessary to turn elsewhere for an understanding of the determinants of individual differences. It is the writer's opinion that these components may be described and studied experimentally. The remainder of the paper presents a description of them. No claim is made that the treatment is other than tentative. Provisional as they are, however, such components possess the attributes of making psychological and biological sense. They derive in the main from facts collected in the psychological and genetics laboratory and from the theories of learning and of the gene. Much information may be secured from a shameless resort to introspection.

Before a description of these determinants is attempted, it is necessary to note the character of psychological measurements which elicit them. These are the objective tests of ability, aptitude, achievement, etc., having subject matter ranging from problems requiring responses which depend upon relatively unspecialized training (such as those in so-called 'intelligence' tests) to problems requiring responses which depend upon a more special course of formalized education (such as those in achievement tests). In addition to these measures, there are the personality tests, ordinarily having the form of standardized questionnaires or associate's ratings. Some of these domains of behavior are relatively easily defined, and item-situations satisfying the definitions are relatively easily selected, *e.g.*, achievement domains of spelling, grammar, reading, arithmetic, vocabulary, and the like; others are more difficult to define and present a greater problem of item selection. The significant fact

to observe about mental measurement is that, having marked out by definition some domain for testing, the psychologist chooses as a *method of measurement* one which indicates that he knows *before giving the test to any subjects* a great deal about the nature of the factors which cause individual differences in the domain. The method is that of *sampling* behavior, and it definitely presupposes that for any defined domain there exists a *universe* of causes, or factors, or components determining individual differences. Each test-item attempts to 'tap' one or more of these components. Part of his very method is also that of choosing items which manifest low intercorrelations, a procedure which shows that the test-maker postulates a large number of *different* components. Further, his method usually requires a selection of a *large number* of items, a procedure which shows that the test-maker believes that the components causing individual differences in the defined domain occur in large numbers. The fact that he subsumes all the items under the same abstract definition of domain does not mean that he assumes the existence of any *general* differentiae of ability in the domain. His inclusion within the same domain of all the diverse items put there involves no assumptions about the factorial bases of the responses to the many items; his laying out of the common domain derives from the mundane convenience of arbitrarily choosing to study one *a priori* classification of reactions together. The types of domains which he chooses to study are dictated by the needs of his cultural group and are of value according to their personal, social and economic usefulness or significance.

The welter of components sampled by a given test may best be understood by taking a specific type of test for illustration. I have selected for this purpose Thorndike's well-known measure of intellect *CAVD* (levels *I* to *M*), conceded to be one of the best tests of the group verbal type. Thorndike properly proceeded by marking out by a definition four verbal domains, namely, sentence completion (*C*), arithmetic (*A*), vocabulary (*V*), and directions (*D*). For each of these domains, he chose many different items satisfying the defini-

tion of the domain. Consider the *V* part: it contains 50 vocabulary items. Why this large number? In selecting such an array has not the test-maker tacitly granted that there are many factors determining differences in the knowing and naming of words, and that only a copious sample of items can in an adequate manner cover the complex substrata of word-knowing? The possibility of a general single verbal factor functioning as a unity may occur to him as a mathematical after-thought, but when he builds his test he proceeds on the basis of a theory of factorial complexity. A test, then, in its very construction plainly implies a multiplicity of factors determining individual differences.

Properties of Psychological Components

We shall review the properties of the psychological determinants of individual differences under the same rubrics used in the summary of the assumptions involved in the postulation of mathematical factors. The components involved in 'intelligence' and achievement domains will be dealt with first.

Number of determinants.—How many determinants are involved in the causation of differences in total score on, for example, *CAVD?* Consider, for simplicity, only the *V* section. The universe of psychological determinants sampled here are the great hosts of *concepts with appropriate names* which come under the domain label, 'vocabulary.' The *V* section samples this universe by presenting 50 multiple-choice vocabulary items, beginning with 'confess' and ending with 'chastity.' There are probably more than 50 concepts involved in these 50 items, since the passing of each item requires not only knowing its conceptual basis and its linguistic mode, but, because of the multiple-choice character of the item, also the conceptual bases and names of some of the incorrect 'test' words. Individual differences in total *V* score will be roughly proportional to the *number* of these concepts which the subjects have formed and named. The evidence as to the multiplicity of such conceptual components derives primarily from a consideration of the concepts elicited in

working on these items in the testing situation, and from a study of the original learning of the concepts and their appropriate words. The subject taking this test is aware of the wealth of concepts which he must bring to bear on such a list of words. Every school boy knows of the multiplicity of conditions involved in the learning of 50 such words as these; no unifying general verbal factor exists for him. In addition to the vocabulary section of *CAVD*, there are 50 *A*'s, 50 *V*'s and 50 *D*'s. The number of concepts which a subject must have formed and have at command before he may earn a high score on this test runs into hundreds. The final level of total score earned by different subjects is to a large extent determined by the total number of these possessed.

Believers in general or group factors may immediately object to this conception of determiners of mental differences by protesting that they do not mean by 'factors' those mentioned above; what *they* mean are the fundamental underlying 'functional unities' which enable the individual *to form* the welter of concepts measured by tests. We shall consider this doctrine later in this paper. It should be evident, however, that the first and proper function of the psychologist is to study and describe the palpable psychological components which determine mental differences. When he does this, he is immediately struck by the large number and complexity, and not by an organized, simplified array of *psychological* 'unities.'

Interrelation between determinants.—The concepts measured by 'verbal tests' appear to be *functionally independent* of each other. By functional independence I mean that the possession and use of one concept necessary to pass one or a few items does not necessarily predicate the possession and use of other concepts necessary to pass other blocks of items. In *CAVD* one may know the concept, 'confess,' but not that of 'chastity'; one may possess the concepts necessary to pass '30 − 7 = ?,' but not those necessary to solve '20 = (2/3)x'; one may form the concepts necessary to fill in the blanks in 'The ———— way to ———— is by airplane,' but not those in 'The ———— old days are often ———— with the present.'

Paradoxically, however, though such concepts are *functionally* independent in a *given* individual, when arrays of different individuals are studied objectively, one frequently finds a positive correlation between the presences and absences of different concepts sampled by a test. Thus it appears that the individuals who tend to pass one group of hard items in a test tend to pass other groups of hard items involving functionally quite different concepts. Likewise individuals who fail in the first tend on the average to fail in the second. It is such positive correlation between different items or different blocks of items which has been termed 'internal consistency,' a phenomenon which has misled many psychologists to educe from it the existence of a common 'functional core' or factor determining success. Such positive correlation may arise, however, from a number of 'external' agencies, and not from common conceptual content. One such agency is systematic difference among individuals in the general quality of the educational and cultural medium in which the different concepts are evolved. To illustrate, if individual *A* is reared in a general educational medium which presents superior opportunities and demands for learning verbal concepts, he will be superior in the knowledge of a large number of quite different verbal concepts, even though these concepts are entirely independent with respect to content and form and with respect to the *specific* environmental fields in which he evolves them. Individual *B*, if reared in a general cultural medium manifesting inferior opportunities and demands for eduction of verbal concepts, will analogously manifest deficiencies in the knowledge of many diverse blocks of such concepts. Thus, functionally quite independent concepts may display correlation in a test situation (*i.e.*, internal consistency) because of a correlation between the environmental fields in which they evolved, and not because of any psychological unity *in* the individuals.[2]

[2] If one chooses to call the general agencies which occasion the correlation between environmental fields, 'general' or 'group' factors, such appellations may, I presume, be valid. It should be noted, however, that such a meaning is not the one usually given to such factors by factor analysts.

Combination of determinants.—It would seem naive psychologically to assume that the components of mental differences combine by simple addition. To be sure, one adds up the item responses of an individual to secure his total score, but from this it cannot be inferred that the numerous concepts which he employs in producing these responses have combined psychologically by addition in his solution of any particular item or a group of them. I need not bore the reader by presenting Gestalt experiments which show that the whole is not necessarily the sum of its parts. In a vocabulary test the subject brings to the problems a large number of concepts which he may employ in diverse and complex ways. In solving some problems he may employ previously formed concepts; for other problems such as those in many 'intelligence' tests, he may evolve for the first time quite new concepts which, though grounded upon previously formed old concepts, may manifest new emergent properties not characteristic of the old. The interaction of concepts used in the solution of such complex problems as those presented in *CAVD*, for example, is doubtless multiform. To envisage them, or the results of their use, as the expression of a simple addition of some sort of elementary psychic 'stuff' would be to indulge in an aprioristic fiction.

Weight of determinants.—The number of concepts and the manner in which they combine in producing a total response on a test is closely tied up with the problem of the weight of each concept in producing the total score. Consider the case of two individuals who earn the *same* total score. One individual might employ 25 functionally independent concepts in getting this score, the other many hundreds. This may be illustrated in a test involving arithmetic problems; in earning the same total score one subject may employ algebraic equations, the other simple rule-of-the-thumb arithmetic operations. The weight of each of the concepts in determining the total score of each individual would be quite different, in fact, quite indeterminate because of their dynamic non-additive character.

Nature of determinants.—Mathematical factors, it may be

recalled, suffer as a major defect from the fact that their psychological nature remains unknown. No such perversity characterizes psychological determinants. In the domains of cognition, it has been suggested above that they are concepts and conceptual relations. The study of them has been a major problem in the experimental psychology of perception, learning and thinking. In addition to the experimental attack, introspection provides another approach. In such tests as *CAVD*, and other group verbal types which, in their more difficult levels at least, are primarily measures of concepts formed in school situations, the psychological nature of the concepts sampled may best be understood from a study of the experimental and introspective psychology of reading, vocabulary knowledge, arithmetic and algebra. Briefly it may be said that a concept has the following aspects or properties: it possesses (1) *form* (or *process*), this ranging from simple contiguous relations or associations between stimuli or events to highly complex types of relations or abstractions; (2) *content* (or *subject matter*) which refers primarily to the specific meaning or significance it has for the experiencer; (3) *retentivity*, which refers to its stability or persistence through time, the degree of which is conditioned by frequency, recency, intensity, etc.; and (4) *degree of generality* or transfer. Stating the features of concepts in the above ways is only one manner of describing them; there are doubtless others. This much is true, however: if a concept is studied in terms of its form, content, retentivity, and degree of generality, a reasonably good description of it as a functional psychological entity in the subject's adjustment to his environmental field will be obtained.

The degree of generality of concepts sampled by tests is of special interest here for the reason that this property of concepts determines, in part, the intercorrelation between test items and between tests. Consider, for instance, the concepts measured by 'verbal tests.' Some concepts may have the most limited application, as, for example, 'hoof,' making for successful response in but a few item-situations; others may have the most general application, as, for example,

certain basic verbs like 'make,' resulting, if known, in a successful response in a wide variety of verbal situations. Consider the negligible effect of ignorance of such concepts as, for example, 'bite,' 'cook,' 'howl' on a total score in a test as compared with the disastrous effects of ignorance of such concepts as 'go,' 'be,' 'do.' The difference lies in the degrees of generality of each. Verbal tests sample hosts of such concepts, these differing widely in their several degrees of generality. Quite different verbal tests usually sample many of the same ones, especially those of the more generalized types, a fact which partially accounts for the positive correlations usually found.

Origin of determinants.—A final consideration is a statement of the origin of the psychological components determining mental differences. For this, we must turn to studies on the evolution of concepts, on insight, and on reasoning.[3] Briefly stated, concepts come into being in the following manner: when the subject is faced by a problem-situation requiring for solution a given concept or group of concepts, if the *psychological field* is properly organized, one may evolve the necessary concept or concepts adequate for the solution of the problem. By the 'psychological field' is meant *both* the presence and sentience of an adequate environmental external field and the presence of an adequate *conceptual background* in the light of which the external field is observed. By being 'properly organized' is meant that the external field features and the conceptual background must be experienced in a certain *form* or *relation*. The whole relational set-up must be 'right' or the concept may not evolve. It turns out to be pretty much of an all-or-none matter, as experiments on insight show. Even though these conditions are adequate, the concept may not come off. A further requirement is that the experiencer must have an adequate

[3] Of special relevance are the following references:

N. R. F. Maier, Reasoning in humans. I. On direction, *J. Comp. Psychol.*, 1930, 10, 115–143; II. The solution of a problem and its appearance in consciousness, *J. Comp. Psychol.*, 1931, 12, 181–194.

N. R. F. Maier, An aspect of human reasoning, *Brit. J. Psychol.*, 1933, 24, 144–155.

E. C. Tolman, Purposive behavior in animals and men, N. Y.: Century, 1932.

genetically determined somatic constitution. As an illustration of these conditions, the writer recalls the situation in which he is confronted with the problem of developing the concept, 'probable error,' in an elementary statistics class. Before the student can evolve this concept, a conceptual background comprising certain basic concepts must first be evolved in him, then an external field consisting of black-board material and verbal details must be arranged in a certain form and *in relation to* the conceptual background. Then the student may 'click,' or he may not. If he does not, the conceptual bases are examined and clarified, and different external fields are arranged for him in the hope that one of these may work. With certain students, of course, either the instructor is unable to organize the right psychological field for them, or, even if properly organized, they may natively lack the somatic complexity necessary for the execution of this particular type of insight. With reference to the concepts measured in such a test as *CAVD*, the question of how these are formed should properly be referred to teachers of vocabulary, reading, arithmetic, and algebra. In vocabulary education, the problem appears to be, first, that of presenting the subject with adequate psychological fields so that he may 'insight' the innumerable concepts necessary, and second, that of teaching him to affix the proper *name* to each of these concepts. The *V* element of *CAVD* measures the number of successes which the subject has attained in many past situations.

Universality of Psychological Components

The confinement of the above discussion to the determination of mental differences in cognitive domains, such as those measured by *CAVD* and similar tests, has been an unnecessary restriction. For the psychological determinants of individual differences in 'personality' domains, whether measured by questionnaires or ratings, have characteristics analogous to the conceptual components described above. In any defined personality domain, whether it be neuroticism, angers, fears, annoyances, interests, attitudes, coöperation, deceit,

persistence, etc., there exist in individuals motivational and emotional dispositions or sets for action and feeling. A 'personality test' samples by its items a defined universe of these dispositions, which appear to be vast in number, functionally independent of each other, though, like conceptual components, often correlated by virtue of certain generalized external and biological agencies, and they combine in more complex ways than by simple summation. Demands for brevity prevent a treatment, similar to that given above to conceptual components, being presented here. For an understanding of the psychological nature and origin of these sets and dispositions, one must turn to the experimental study on the origin and nature of the emotions, drives, aversions, etc. In these domains of behavior, though not yet submitted to the intensive program of measurement as have been the cognitive, any attempts to educe general or group mathematical factors from intercorrelations will result in the same fictitious simplifications as have been proposed in the realms of abilities.

Properties of the Fundamental Causes of Capacities and Predispositions

Those who embrace the conception of broad general or group factors may admit that the above psychological description of the causes of mental differences is cogent, and possibly acceptable to them. But they will probably object to such an interpretation as not constituting the whole case for factors. What *they* mean by such factors as *g*, *verbality*, *number*, *space*, *etc.*, are the more 'fundamental unities' which determine the individual's *capacity* or *pre*disposition to form the concepts and sets measured by cognitive tests, questionnaires, and ratings. They will claim that both the psychological and mathematical interpretations could be advocated without contradiction. The cogency of such a claim depends entirely upon what is meant by fundamental unities. If the meaning is that the general or broad group factors represent the fundamental *causes* of differences in capacities and predispositions, then the available experimental evidence on the nature of such causes precludes the postulation of

general or broad group factors. There seem to be two types of fundamental causes, hereditary factors and environmental fields. We must now consider the properties of these causes with special reference to completing our own systematic treatment, and incidentally to showing that general and group factors may not be interpreted as these.

Hereditary determinants.—Is it not possible that the general factors proposed by the mathematicians represent specific hereditary unitary components? May not, for example, Spearman's *g*, which supposedly is a major determinant of differences in *CAVD* scores (let us recall Holzinger's declaration: '*CAVD* is full of *g*'), represent a stable hereditary variable which saturates in different degrees all cognitive traits? May not broad group factors also be hereditary? The reply to these queries is simply that there is no evidence to support an affirmative answer. To the geneticist, a factor or component is a *gene*, or more properly, a *locus* in a chromosome. A number of genetic studies have been made on quantitative structures which, like mental abilities, are more or less normally distributed. The geneticist's conclusions are that for such characters, no simplified set-up such as that postulated by the *G* and *P* theories occurs genetically, but that multiple, independently assorting genes, or Mendelian factors, are operative.

Most of the evidence on the properties of genetic factors has derived from the study of animal and plant structures; little work has been done on behavior. These properties, experimentally observed, may be summarized as follows. (1) As to the *number* of genetic factors, there are doubtless thousands of them in the 24 pairs of chromosomes of human beings, for in the fruit-fly, *Drosophila melanogaster*, with only four pairs of chromosomes, a conservative estimate is 4,000. (2) With respect to *interrelation* between them, they manifest independence in their distribution to progeny, that is, different factors in different chromosomes assort independently, different factors in the same chromosome lose correlated association by 'crossing-over.' (3) As to *combination* and interaction, in the case of normally distributed characters, where blocks of

multiple independent genes provide the factorial basis, the genes of the block do not inevitably combine by simple cumulation in the forming of the phenotype but frequently in more complex ways as is the case with duplicate and complementary factors. (4) As to the *nature* of the gene, it manifests a definite *content* of an as yet unknown biochemical constitution which provides the basis for the different characters, a degree of *stability* which, except for rare mutation, is one of permanence, and a degree of *generality* with respect to the extent of effect it has on different tissues of the soma. (5) As to the *origin* of genes and gene blocks, the process is one of mutation, supplemented by fragmentation, duplication, polyploidy, etc.

The vast numbers of somatic structures in the body possess as their genetic basis an exceedingly complex matrix of genes interacting in complex ways, hence such a simplified factorial pattern as that suggested by mathematical-factorists is not consistent with a proper conception of Mendelian factors. It follows, therefore, that a mathematical factor cannot be conceived of as *an* hereditary factor. May it not then be argued that a mathematical factor, instead of being a single gene, is a block of genes, this block behaving as a stable unity affecting many tissues and hence a great variety of behaviors? I have found no evidence in *Drosophila* studies that a group of genes functions together in a stable unvarying equilibrium as *partial* determiners of a variety of different tissues. Since different behaviors appear to bring into play different tissues,[4] and since there is no evidence to indicate that a stable block of genes operates as a common genetic matrix in determining diverse tissues, no basis exists for assuming that a group of genes constitutes a general or group genetic factor.

A certain risk is involved in our eduction of the properties of the genes determining differences in mental abilities and temperamental characters from those known to determine differences in structures. Crucial evidence must come from genetic studies of behavior differences. Such evidence is

[4] In this connection, see the interesting treatise by J. A. Gengerelli, Brain fields and the learning process, *Psychol. Monog.*, 1934, **45**, No. 4, p. 115.

virtually non-existent, for psychologists have been slow to seize upon the techniques of the geneticists and to apply them to a study of the Mendelian bases of behavior. The writer has been making an attempt along this line for a number of years. His experiment aims at a discovery of the nature of the genetic factors determining individual differences in maze-learning in rats. Here we have *behavior*. The results to date shed sufficient light on the problem to warrant a brief statement of them.

The rats are reared and run through a maze under conditions of rigorous environmental control. Individual differences in ability to learn the maze are wide and consistent. This fact itself seems to indicate the operation of multiple independently assorting genes. The evidence is not crucial, however, because of the possibility that the differences in learning might be determined by environmental variations impossible to control. For crucial evidence it is necessary to proceed with selective breeding for maze-brightness and maze-dullness. Such selective breeding has now been continued to the eleventh generation, with the result that we possess two races of rats, one breeding relatively true for maze-brightness, the other for maze-dullness. There is negligible overlap between the two races.[5] The significant fact appears that the effects of selective breeding are quite *gradual*, a phenomenon indicating that we are here working with a complex block of genes determining *this specific ability*. Selective breeding results in the gradual sorting into one pile, as it were, of all the genes determining capacity for superiority in this maze ability—the bright race—and into another pile, of all the genes determining inferior capacity—the dull race. Crucial tests have been made, namely, the breeding of bright rats to dull, the F_1 of which were then inbred, giving the F_2. Among these progeny arose rats of all degrees of ability, indicating clearly recombination effects among the many genes involved in the functional matrix determining this

[5] R. C. Tryon, The genetics of learning ability in rats—a preliminary report, *Univ. Calif. Publ. Psychol.*, 1929, 4, 71–85. Graphs of results secured since the publication of the preliminary report appear in F. Moss, (Ed.) Comparative psychology, N. Y.: Prentice-Hall, 1934, Chap. XIII, 'Individual differences' by R. C. Tryon.

ability. One is led to conclude from all these results that the genes determining capacity in this problem-solving behavior are exceeding numerous and complex in their production of the phenotype.

Evidence on the genetic determination of the activity of rats has recently been published by Rundquist,[6] who found gradual effects of selective breeding for active and inactive rats. The effects here were somewhat more rapid than in the maze experiment, suggesting that there are probably fewer genes involved in determining differences in activity than in maze ability.

Returning to human-beings and mental tests, the above treatment may shed some light on the role of genetic factors in determining the *capacities* for the evolution of concepts. It must be kept in mind that such a test as *CAVD*, for example, is a sample of many diverse conceptual operations, involving the participation of many different somatic tissues (brain fields, sensoria, musculatures, etc.) brought into action by many past and present environmental fields. In the evolution of the many concepts sampled by the test, great masses of somatic tissues are and have been involved, and hence the different gene blocks that determine the relative efficiencies or capacities of these tissues constitute the fundamental determinants of this ability. Thus it is that a test, insofar as heredity affects the performance, *indirectly samples a large group of genes*. Different tests may sample different groups.

Environmental fields.—The second class of fundamental causes of individual differences in abilities and other behaviors is that of *external environmental fields*. In order to describe the properties of these fields, one must hold genetic variance constant. Let us specify this treatment by asking the question: What are the properties of the environmental fields which determine differences in *CAVD* score between two individuals of exactly the same genetic constitution? These properties may be described under the heads considered above. As to *number*, there are countless ways in which environmental

[6] E. A. Rundquist, Inheritance of spontaneous activity in rats, *J. Comp. Psychol.*, 1933, 16, 415–438.

fields may differ for identical genotypes, each way having its own unique effects on behavior. It is to be recalled that the psychological field not only includes the external situation presented to the individual, but also the conceptual background. Among identical genotypes differences in this conceptual mass are determined by differences in previously presented external fields. Thus the number of present and previously presented external fields that may produce differences in performance among identical genotypes is infinitely large. In mental tests such as the Binet, an effort has been made by a standardization of test procedure to control the immediately presented external field, and by a selection of 'common every-day' content to hold constant differences in previously presented fields, thus leaving as the sole source of variance the hereditary differences among individuals. So numerous are the fields which affect performance, that such efforts have been attended by little success, as is evidenced by the wide divergence in I.Q. discovered among some identical twins reared apart.[7] As to the *interrelation* between environmental fields, they appear to manifest physical independence. For example, the specific external conditions presented the individual in endeavoring to get him to form vocabulary concepts are arranged for him independently of those in which he develops arithmetic concepts. Likewise, the specific stimulus conditions arranged for his evolving a *given* verbal concept are physically independent of those arranged for other verbal concepts. The problem of the *combination* of external fields is one of great complexity. That fields should combine either physically or psychologically by summation is inconceivable. Certainly the disparate stimuli which make up a given external field are not experienced by the individual as a summation but ordinarily as a pattern; indeed, this fact was the basis of our choice of the term, *field*. The physical *nature* of external fields may be described in terms of the forms and patterns of physical energy presented to and perceived by the experiencer. With

[7] A summary of the evidence on identical twins reared apart appears in G. Schwesinger, Heredity and environment, N. Y.: Macmillan, 1933, 209–233.

reference to the *origin* of external fields in the individual's experience, these may be classified into the adventitious fields in which the individual accidentally finds himself, those formally and systematically prepared for him by his societal culture, and those which he seeks out himself. Such complexity faces us in our envisagement of external environmental fields that it would be egregious oversimplification to believe that general or group factors proposed by mathematical factorists may be conceived as these.

In the determination of the psychological components of ability and temperament, genetic determinants and environmental fields often interact in such ways that, among human beings at least, it is ordinarily impossible experimentally to hold one constant while studying variation in the other. The reason for this difficulty is that, though physically independent variables, these two types of causes often manifest a correlation. Thus in an economic and educational caste or class system, which often results in a tendency of inbreeding, different types of genotypes tend to become confined to different types of environmental fields. Even under *laissez faire* conditions correlation may appear: individuals possessing superior genetic constitutions for special excellence in certain classes of environmental fields tend to seek out and provide themselves with special superior fields befitting their innately superior predispositions.

Variability of the Individual

The above view of the conceptual components of mental differences illuminates a number of important problems in mental measurement which are given a fictitious solution by mathematical-factorists. One such problem is that of the so-called 'chance error' of an individual's test score. The mathematical-factorist believes that an individual's response on, say, a given vocabulary item, X_1, in the V element is the sum of *truth*, X_∞, plus an *error*, E_1. Stated equationally and using deviations, $x_1 = x_\infty + e_1$, where the true factor is the summation of all the systematic factors extracted by factor analysis, and the error is 'chance.' The form of the equation

is supposed to hold for all the other test items, x_2, x_3, $\cdots$, the true factor being the *same* for all items, but the errors all being different and independent. The summation of all the items is supposed to result in the cancellation of the chance errors (since uncorrelated), leaving in the total score the truth, except for a minimal total chance error. This conception of truth and error is, however, psychologically absurd. Suppose, for example, that in the *V* element in *CAVD* one passes the item, 'confess,' and fails 'chastity.' What is the identical core of 'truth' in both of these responses, and what are the two residual chance errors? The truth-error postulation is quite legitimate, *mathematically*, and many of the formulae referring to the reliability of measurement may be deduced from it,[8] but it has no psychological meaning.

The error of an individual's *total* score may be estimated from one of these formulae. This error represents the variability among the total scores of a given individual on many tests exactly comparable in content and form. Under the truth-error doctrine, this variability is supposed to be due to minimal chance errors, each score diverging from some core of truth in the individual because of one such error. All of this is decidedly mysterious—and quite unnecessary. One has only to recall how 'comparable tests' are constructed and to keep in mind the above treatment of the conceptual components of ability in order to understand why an individual differs in his scores on comparable tests. His variability is due, not to some mysterious undefinable error, but to the fact that though each test samples the same universe of concepts the samples may differ in many particulars.[9] With respect to those concepts in which the tests differ, an individual may pass those in one test and fail those in the other. In general,

[8] See L. L. Thurstone, The reliability and validity of tests, Ann Arbor: Edwards Bros., Inc., 1931; and R. C. Tryon, The reliability coefficient as a per cent, with application to correlation between abilities, PSYCHOL. REV., 1930, 37, 140–157.

[9] There is an increasing tendency for writers to term $\sqrt{r}$ as the 'theoretical validity' of a given measure whose reliability coefficient is r. Since $\sqrt{r}$ is the correlation between the given sample and the universe of measures from which it is drawn, the value indicates how valid a measure of the universe the given sample is. For a discussion of this point, see H. Hartshorne, and M. May, Studies in deceit, N. Y.: Macmillan, 1930, Book II, pp. 118 *ff.*

the error of an individual's score will be significantly affected by the correlation between these residual concepts. The variability is due to 'chance,' not in the sense that the *individual* is unsystematically in error, but in the sense that the test-maker has by chance put in one test some items requiring the use of some concepts not required by items in the other test. In fact, two comparable tests give correlations less than unity for the same reason that two non-comparable tests do, namely, because in some degree they measure two somewhat different conceptual complexes. Only when two comparable tests contain so many items that they both cover adequately the whole universe of concepts will an individual tend to earn the same total score on both tests.

Rationale of the Correlation between Psychological Domains

Community ('overlap') of multiple psychological components.—In the foregoing pages, we have dealt primarily with the causes of mental differences in a single sample from a defined universe of psychological determinants. A proper conception of these components leads us directly to a description of how they operate to produce a correlation between *different* psychological domains. It has been the study of the intercorrelations between mental measures which has lead mathematicians to postulate their general and group factors. Consider the case, for instance, of the correlations between *CAVD* and other group 'intelligence' tests, such as *Otis, Alpha, Terman, National* etc. In a fairly random sample of individuals homogeneous in age, the true intercorrelations cluster around .90. On the other hand, correlations between such verbal tests and mechanical, non-verbal, and performance tests, and measures of 'narrow' verbal domains, such as immediate verbal memory, etc., are very much lower, though ordinarily positive. To a mathematical-factorist, these positive coefficients indicate the presence of a single general factor and/or a few broad group factors. The psychological interpretation, however, is that the magnitude of each positive coefficient indicates roughly the extent to

which the two tests in question sample similar universes of conceptual components. *CAVD* shows high correlation with *Otis*, *Alpha*, and similar tests, not because some mystic general factor saturates them all heavily, but because all these tests sample to a marked extent the same complex welter of concepts determining vocabulary, reading, and arithmetic abilities. Instead of a single common factor, *there are innumerable common conceptual components*, which possess the properties indicated earlier in this paper. *CAVD* shows a low correlation with non-language tests and tests of narrow verbal domains because each test tends only to a limited degree to sample the same domains of conceptual components sampled by the others.

Correlation between independent environmental fields.—This overlap of numerous psychological components is not, however, the sole source of positive intercorrelation between tests. Often it appears that two tests which on analysis seem to sample in *no* degree identical psychological components nevertheless give positive intercorrelations. Indeed it is customarily observed that any table of intercorrelations between a diversity of cognitive domains rarely shows a single coefficient that is not positive. From such facts as this, some psychologists conclude that here, finally, is definite evidence of a single general factor. This conclusion is, however, a too simple eduction, for there are more cogent reasons for such universal positive correlation. It is very doubtful whether any two cognitive tests of however different subject matter could be given to a random population without eliciting an overlap of some conceptual, emotional, and motivational dispositions. But over and above this overlap there are other explanations of positive intercorrelation. Consider the case of the correlation between a vocabulary test and an arithmetic computation test. Even if the computation test be so administered that no verbal commands or words of any sort were employed, a positive correlation would appear between these two measures. No one could seriously doubt, however, that the subjects, or at least some of them, would bring to bear on the two tests *some* common concepts,

emotions and motivations which would account for some of the positive correlation.

But another source of this correlation is that mentioned earlier in our explanation of 'internal consistency,' namely, the phenomenon of correlation between the environmental fields in which the different psychological components are originated. How this phenomenon operates to occasion a positive correlation between the illustrative vocabulary and computation tests should be evident. Individuals who, in the home, school, or general educational medium, are formally presented with the special environmental fields which elicit superior verbal concepts, tend *also* by the operation of these general cultural media to be exposed to the special environmental fields which elicit the formation of concepts basic to superior arithmetic computation. Analogously, a generally inferior cultural medium would lack many special environmental fields necessary for the formation of *both* verbal and computational concepts, the consequence being that the individual suffering such lacks would fail to develop much knowledge and skill in both achievement domains. In a social system where families and individuals suffer wide differences in general social, economic, and educational status, a positive correlation occurs between the qualities of the many special environmental fields necessary for the evolution of quite different blocks of concepts. Such phenomena would produce a positive correlation between verbal and computational concepts, even though for the individual they would be actually functionally quite independent. Thus, two *tests* sampling these two quite independent blocks of concepts would show a positive correlation. The manifest intercorrelation between physically independent environmental fields due to such general agencies as educational opportunity and culture appears to be an important source of the general positive intercorrelation universally observed between quite diverse cognitive measures. Such a phenomenon is a general 'factor' of a sort, but it is not a general psychological functional unity or 'core' within the individual. The general common factor lies not within him, but in his cultural background.

Correlation between independent gene-blocks.—The second phenomenon that accounts in part for the general positive correlation between diverse mental measures also lies back in the fundamental causes of mental differences. It is the correlation between independent gene-blocks. It results from one type of assortative mating among parents. Males tend to mate with females of their own *general* economic, educational and cultural status. As a consequence men and women of genetic superiority for achievement in quite *different* domains tend to interbreed, as well as do those of diverse inferiority. On the genetic side, what happens, then, is that individuals possessing blocks of genes determining superior capacity for one type of achievement unite with individuals possessing blocks for superior capacity in another. Their offspring, in consequence, tend to receive genes for superior capacity in *both* types of achievement. Assortative mating of individuals inferior in diverse gene-blocks results in a distribution to their offspring of inferior genes for capacity in diverse abilities. Whereas the genes affecting different abilities are physically independent, this type of assortative mating produces a positive correlation in their phenotypic expressions. Here the positive correlation between different abilities is occasioned by no general genetic factors in the individual; the common factor lies one or more generations back.

The correlations between environmental fields and between gene-blocks are not of high magnitude. That they are low is evidenced by the fact that the actual objective correlation between measures possessing a negligible overlap of psychological components is quite low. Crucial evidence of the operation of such agencies can apparently be secured only in the animal psychological laboratory, where control of environmental fields and systems of breeding is possible. Ordinarily environmental control and random breeding are instituted as a matter of routine in the animal laboratory. It is therefore of interest to discover that in the few and as yet inadequate studies made on laboratory rats, where the correlations between environmental fields and between inde-

pendent gene-blocks are avoided, there appears no evidence of a significant positive correlation between such diverse domains as maze-learning, problem-box learning, and visual-sign learning,[10] tasks which apparently involve environmental fields so different as to elicit a negligible overlap of conceptual components. It is to be concluded that if the correlation between independent environmental fields and between independent gene-blocks were zero, tests involving no communality of psychological components would show intercorrelations of zero.

Summary

Theories which postulate 'mathematical factors' as the determinants of individual differences involve assumptions that do not possess psychological or genetic validity. As an alternative, a theory of psychological components is presented. These determinants are considered to be concepts, and motivational and emotional dispositions. They exist in large numbers, manifest functional independence, combine in complex ways not necessarily summative, display relatively indeterminate weights in producing a reaction, possess form, content, retentivity, and degree of generality as definitive features. Each component originates in a psychological, relational field consisting of an external environmental field and a conceptual background, and requires as a necessary condition for emergence an adequate somatic constitution. Psychological 'tests' are samples of such components from an *a priori* defined universe or domain of components. Variation of an individual on different forms of a test is due not to a mysterious factor of 'chance' but largely to non-identity of the components sampled by each form. The fundamental causes of the capacities to form the innumerable components are gene loci and environmental fields, these manifesting great multiplicity, independence, complex interaction, indeterminacy of weighting, and other definitive features. Knowledge of these psychological components and of their fundamental

[10] For a summary of this type of evidence, see F. Moss, (Ed.) Comparative psychology, Chap. XIII, 'Individual Differences,' pp. 440 *ff.* and M. Tomilin, and C. P. Stone, Intercorrelations of measures of learning in the albino rat, *J. Comp. Psychol.*, 1934, 17, 73–88.

causes provides a rationale for the intercorrelation between tests or behavior samples. Positive correlation between two tests is conditioned by the extent of community of components, by the degree of correlation between the environmental fields in which the components sampled by the two tests originate, and by the degree of correlation between the gene-blocks determining the somatic tissues brought into action by the two tests.

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THE EVOLUTION OF MIND

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The present year is the occasion for celebrating the 75th anniversary of Darwin's epoch-making volume 'On the origin of species,' first published on November 24th, 1859. The temptation is therefore strong to observe in retrospect the tremendous revolution that book introduced into the thinking of scientists. But what is eminently more important is to inquire into the fate of the doctrine itself. Is Darwinism dead? And if so, does that affect the evolutionary theory?

It is the purpose of this article to show that whatever fault may be found with various particulars in Darwin's version of evolutionary theory, his fundamental conception not only stands impregnable, but is just beginning to reveal its unique value for the understanding of the origin of the human mind.

II

The history of the 19th century has amply celebrated the advent of Darwin's memorable book. The great revolution which the establishment of the doctrine of biological evolution brought about in every field of thought is a matter of accurate record. Everybody is familiar with the breath of freedom that evolution blew through the thought concerning religion, how it quickened the investigation of the origins of law, social life, and art, and gave rise to invaluable comparative biological studies—the latter leading to much of what we know of the organic world.

But what of the doctrine itself? That is another story. Darwin's own conceptions concerning the processes of organic evolution were not always of the happiest. Certainly his conception of sexual selection has nothing to recommend it. And it is possible that the whole idea of natural selection

may not be at all the clue to the differentiation of species. Now the question arises: Is the fate of evolution tied up with the destiny of Darwin's explanation of the descent of animals? Darwin himself did not believe that. Were he alive today, he would be the first to recognize how little some of his own ideas support evolution and how severely the accretion of knowledge calls for a modification of his statements. It is obvious then that before we can discuss how much weight the doctrine had and still has, and whether it is applicable outside of biology, we must consider what it truly signifies.

III

To begin with, the theory of evolution which we date back to Darwin's time should not be confused with the concept of general evolution—a theory referring to the eternal modification of things and discussed ever since the time of the Greeks. As we shall presently see, it is the mistaken conception of a general evolution of things that has had an unsatisfactory history in the fields of anthropology and psychology.

Evolution, in the Darwinian sense, means the specific process of transformation of biological species. But it also means something more—namely, that the specific process must be accounted for on the basis of very definite happenings. The great admiration which we have for Darwin, despite the derogatory attitude taken toward his conception of natural selection, is based upon the fact that he spent years gathering data that would throw light on the specific occurrences in the evolution of species. This is why Darwin's name became so intimately connected with the theory. Fundamentally then evolution refers to the natural history of a phenomenon, whether it is a particular kind of animal, a social institution, or a mind. As far as biological species are concerned, the important question is not whether Darwin's natural selection is to be replaced by mutations or some other mechanism as the cause of origin. The salient point is the search for specific evidences of actually occurring events. That this was Darwin's idea is brought home to us on every page of 'The

origins,' since he is constantly comparing the generalized assertion of special creation with the records that show modification as specific happenings. This explains why Darwin was so keen on the idea of the gradual accumulation of imperceptibly small variations.

Evolution as the natural history of existing things is an established doctrine. Upon this all scientists agree. The theorist of evolution therefore stands firmly opposed to all attempts to set up arbitrary steps in a series in order to explain the present existence of anything. Evolution accordingly becomes a definite technique for explaining how a summation of actually occurring events has contributed to the origin of a phenomenon. On this basis the principle of evolution can be applied to phenomena that are only partially, or not at all, biological in character.

The difficulties confronting scholars who attempt to apply evolutionary principles to non-biological facts are owing not to the fact that evolution refers only to biology, but precisely to their overlooking the principle of detailed factual development. In other words, they deal in generalizations.

Consider two examples, the first anthropological. So imbued were Spencer and Tylor with the idea of applying general evolution to human societies that they developed a conception of the unilinear evolution of our current complex civilization from such types of simpler civilization as now exist in Africa, America, and Australia. In other words, current primitive societies were presumed to constitute the earlier stages of our own civilization. In order to show this straight line of evolution they made arbitrary and fallacious selections from the numerous facts of these different human systems. But what a violation of the fundamental principles of evolution! Instead of tracing out the concrete factors in civilization change, they chose rather to set up grand scale features. It is evident of course that our civilization did not develop from the primitive civilization of living tribes but that each had its own evolution parallel with the others in detail and time.

A similar unhappy application of evolution we find in the psychological domain. Stimulated by the great stir of Darwinism, students of the mind tried to work out straight line evolutions from simpler to more complex mentality. Quite erroneously the mind became regarded as some sort of generalized quality which showed a progressive tendency toward complexity and betterment. If we follow through the details of this history, beginning, say, with the work of Francis Galton, we find a peculiar paradox. It is nothing less than the denial of genuine mental evolution. With respect to the individual mind—which is the only kind of mind—the application of evolution to mental life has resulted in making mind, if not a matter of special creation, at least a static phenomenon. Thus arose the conception that each individual comes into the world with a mind fully formed as far as its capacities and powers are concerned, and all that is necessary is to provide it the opportunities to attain achievements comparable with its inherent quality. The reader will readily recognize this conception as the basis for all statements concerning hereditary genius or native intelligence.

Now it is obvious that the psychological life of an organism is intimately interrelated with the biological evolution of the species to which that organism belongs. Mind therefore of necessity is to a great extent a matter of species. No one would attempt to teach a dog the calculus, because obviously the dog belongs to a stage of evolutionary development at which such performances are not to be thought of. But there is no possibility of denying that each human individual who can do calculus can do so only through a personal evolution—a development which must be studied in infinite detail as a set of specific concrete happenings.

Mind is individual. There is no such thing as mind in general. The psychologist who thinks of mind in any other way is hopelessly lost in the morass of mysticism. Moreover, mind is essentially a phenomenon pertaining to particular organisms or persons. Furthermore, mind is not a substance or quality, but action—the ways in which an individual

adapts himself to the things and conditions of his milieu. Now psychological action is always interaction. This means that if I take one of two things offered me, I do so because of an effect that thing has upon me. Both I and the thing are mutually acting upon each other. It appeals to me and I am attracted to it. This interactional process has evolved during the course of my psychological life. Psychologists refer to this evolution as the individual's reactional biography. To trace out the evolution of all the myriads of such interactions summed up by the term *my mind*, means to study as many as possible of the billions of specific conditions which are the unique and indispensable features of that evolution.

Thus we reach the conclusion that in applying evolutionary concepts to the human mind we must not deviate one iota from the fundamental principle of evolution—namely, the study of specific details of origin and development on the basis of concrete events.

Now what are the events involved? There are three types. Mental evolution is a progressive development upon three definite but thoroughly interrelated levels: (1) phylogenetic biological evolution, (2) ontogenetic biological evolution, and (3) psychological evolution.

IV

As we have already pointed out, the mind of an individual as a member of a species is fundamentally tied up with the evolution of that species. This process of species or race development constitutes phylogenetic evolution. Howsoever difficult it is for us to know the exact steps by which there came to be men on earth we cannot overlook the fundamental scientific obligation to trace through this development—in hypothesis at least. Generally speaking, this species-evolution involves complex changes resulting from specific interactions of organisms with environmental conditions, both external and internal to the organism. This development probably proceeds by the accumulation both of slight modifications and large mutational jumps.

To avoid misunderstandings let us point out here that we

are dealing with biological phenomena—concrete organisms. Organisms are describable as correlated facts of organization and function. What the organism does is a function in the mathematical sense of what it is structurally. On the other hand, what the organism consists of structurally is a function of its activities in connection with the objects and conditions with which it is interacting.

Such structure-function facts are not to be confused with psychological phenomena, though they exert an influence upon the distinctively psychological evolution of the individual. Thus the size, shape, and symmetry of the organism have definite, potential influences upon the kind of psychological interactions that can be developed. Consider what possibilities lie in the evolution of postural erectness, hand development, and general agility of the human animal for the development of psychological behavior.

But these potentialities embedded in the biological evolution of the human species must not be regarded as anything more than possibilities for the development of psychological phenomena. They are something upon which to build. But what will be built is not predetermined by what has already been developed. Having received some money one can buy any number of different things. The possession of the money is, however, only one of many necessary factors in the purchase. The object must exist, the possessor of the money must know about it, desire it, and be willing to exchange his money for it. Similarly, the evolution of the human hand makes it possible for the individual to handle a bow, play a piano, manipulate a fork or chopsticks, but it does not determine that any of these activities shall take place.

In this sense we regard the attainment of a certain biological organization as merely a prior factor in the development of psychological activities. To develop the latter it is further necessary that the person undergo infinite details of interaction with environing circumstances of topography, flora and fauna, temperature, and other things. If such interactions favor the development of certain forms of psychological interaction, they will come into existence; if not, others may arise, or none at all.

These potentialities, it must be noted, are really concrete organization and function phenomena, not mysterious determiners. An intellectual check upon any tendency to misunderstand the relations of biological and psychological phenomena we find in the consideration of the human species. There is only one human species. All men are evolutionary brothers, despite their variations in color, size, and shape. Yet what enormous differences in their psychological development—both in comparing different groups (races) and individuals of the same group! Their specific individual differences in psychological character depend upon an evolution postdating the phylogenetic biological evolution.

V

The second or ontogenetic biological evolution of the individual begins at a zero point marking the moment just before the union of the gametes. As soon as the gametes unite there begins an infinitely complex set of interactions of the new individual with environmental conditions. What happens at the very beginning—say in the way of cell multiplication—is influenced by the prior phylogenetic development of the organism's species. The present zygote is only a link in the reproductive cycle which continues the life of the species. What the cells have previously passed through in the way of concrete evolution now has its influence upon the organizational and functional status of the new organism. We must not forget that the individual's original cells are derived from a certain pair of organisms which have passed through a particular kind of phylogenetic evolution.

Next we must think of a tremendous number of interactions of the various cells with each other, and their whole aggregation with external conditions. Howsoever ignorant we may be of the actual details of the interactions involved in an organism's embryological development, we may still be confident that they are immensely detailed biological and chemical processes. Biological in the sense of various influences which prior stages of ontogenetic growth have upon later ones. Chemical in the sense of all sorts of hormone

effects. Then there are numerous types of physical interactions with the immediate environmental circumstances surrounding the organism each moment.

At this point we must be warned against admitting any mystical elements into the embryological story. We must guard against the pitfalls set for us by the teleologists who would inject mysterious forces (entelechies) into the processes marking the individual's progression to the status of a full-fledged species member. For one thing, the zero point we have spoken of is only a scientific indicator to mark the transition from phylogenetic to ontogenetic development—the former evolution determining that the new individual will be like the parents, the latter evolution resulting in differences between parents and offspring. Not to fall back upon so-called teleological causes means to take note of all the concrete happenings that must take place both in the behavior of the gametes themselves and that of the parent organisms from which they spring before it is possible for a biological individual to begin its unique evolutionary career.

It is well known that numerous conditions for the psychological development of the individual are foreshadowed in this second biological evolution. Should abnormal conditions insinuate themselves at this stage, there results an interference with the individual's normal potentialities for psychological development. Such abnormalities are responsible for malformations and dysfunctions culminating in a monstrosity rather than an average biological product. And of course unless embryological development is normal we cannot expect normal psychological growth.

All psychological performances are at the same time biological actions—actions performed by a biological organism. Whatever performance depends upon the presence or normality of an organ is in so far precluded from occurring when those biological conditions are not fulfilled. No person unfortunate enough to be born without legs obviously could ever walk, though he might transport himself otherwise. Nothing is more important at this juncture, however, than a careful consideration of details. Had Beethoven been born

deaf there would never have been a Beethoven, although his deafness may have had little influence on his composing such tremendous works as the Missa Solemnis and the Ninth Symphony. Could Steinmetz have been a greater mathematical physicist had he been born biologically normal? Then we may also speculate as to what precise effects the handlessness of Ducornet (1806–1856), the French painter, or Unthan (1848–1929), the German artist had upon their work.

VI

Not until the second biological evolution is completed to a certain point is there any psychological phenomenon at all. In other words, until that stage of development there is a psychological zero. Only after passing this point does psychological evolution begin. Just as conception marks the emergence of the first beginnings of an embryological individual, so the completion of certain biological stages marks the beginnings of a psychological individual. Obviously, at first, psychological interactions are hardly differentiable from the biological. They consist merely of responses to such phenomena as varying pressures and possibly temperature. This primary stage of psychological evolution undoubtedly takes place before birth, so that the earliest psychological evolution closely parallels late uterine maturation.

As soon as the organism is born and is thus enabled to come into contact with the complicated world of things on its own account, psychological evolution proceeds with a tremendous velocity. Naturally, the early post-natal stages of psychological evolution still follow closely that of the biological processes. Before the child can turn its eyes toward a light, it must develop the necessary neuro-muscular coordinations. Before it can move away from a disagreeable object or toward a desired toy it must be able to creep. At this stage of development the biological and psychological are therefore still closely interrelated.

The most characteristically psychological activities, however, are to a greater and greater extent independent of

biological development. They are, as we have already said, the interactions with objects on the basis of the organism's prior contacts with such objects. The specifically psychological activities are intimately connected with what, for want of a better term, we call social phenomena—those essentially human features of an organism's surroundings. The results of such interactions are the building up of concrete performances of speech, feeling, appreciation of the uses and character of objects, the ability to name things, and so forth throughout a large gamut of equipment.

If we abide by our rule to deal only with concrete facts, we shall in tracing the evolution of mind be studying just such intimate interactions of organisms and stimulus objects. This can be illustrated by an example. The English child is stimulated by a hat to refer to it as *the hat*, whereas the German child's interaction results in calling it *der Hut*. The same object stimulates differently. Thus, psychological action constitutes not merely the coordinated action of muscles, nerves, glands, etc., but a qualitatively specific form of action interrelated with a stimulus function of an object. Actually a single object can have any number of different stimulus functions. As in the case of the hat, each stimulus function is correlated with a different specific configuration of behavior. This interactional phenomenon we take to be the essential fact of mind.

VII

Like all other phenomena mind arises by a definite process of evolution. In particular, mind originates as the development of a large series of definite kinds of behavior from earliest infancy to the last stages of adulthood. It is this development and this development alone which can properly be called evolution of the mind. To follow through the way the individual's concrete interactions are built up means to abide by what is fundamentally Darwin's conception of evolution.

Furthermore, only in this way can we do justice to the fact that the human mind is, on the one hand, rooted in biological, and, on the other, in social phenomena. The phylogenetic evolution through which the organism first

passes gives it a place in the evolutionary scale. In no sense then is it mysticism to say that a human infant is potentially capable of a very different development from some other type of animal. For, the phylogenetic development of the organism constitutes a factual preparation toward a very specific kind of mental product. This final product is, however, in no detailed sense provided by the phylogenetic development. Before there can be any concrete mind at all the organism must pass through an infinite series of contacts with conditions in order to reach the organic status of a biological individual. Even this is not enough, for the child does not come into the world with given mental powers. In order to achieve them he must progress through a step-by-step interactional development in what is predominantly a human world.

Mental evolution, therefore, is a three level process. In its more remote antecedents mind is biological, in its more immediate circumstances, personal and social. Only by studying concrete happenings in these two large fields of events can we find any genuine fact or valid conception concerning the evolution of the mind.

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ENDOCRINE FUNCTION AND PERSONALITY

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As points of reference in considering endocrine influence on personality four questions may be raised: What rôle do the endocrine glands play in producing changes in personality of the individual from birth to senescence? What part do the endocrine glands normally play in making for differences between individuals? What changes may result from malfunction of the endocrine glands? Finally, what changes can be produced by the experimental alteration of amounts of hormone in the body? The kind of evidence necessary for the shaping of final answers to these questions is not available; however, there are certain consistencies in the data already at hand which may well be pointed out.

Capacity for Learning

One cannot question the assertion that changes in the learning ability of the individual between birth and maturity are dependent upon the presence of several homones. Secretions from the suprarenal cortex, parathyroid glands, and pancreas are necessary for life itself, while in addition, the anterior lobe of the pituitary body and the thyroid gland play leading rôles in regulating the growth and function of all tissues of the body. The question as to whether individual differences in intelligence have an endocrine basis has no such simple answer. Variations in endocrine function are recognizable only when very definite anatomic and physiologic changes have occurred in the organism. On the basis of present methods for evaluating endocrine status, clinicians would be able to divide the population into two groups: (1) the 'normal' group, which consists of those who have normal endocrine function, and which includes a large majority of the population; and (2) the 'abnormal' group, which includes

those who have some form of endocrine dysfunction. Within the 'abnormal' group, definite pathologic changes would be present in most cases. Some quantitative evaluation could be reliably placed on the severity of the disorder. So little is known of variations in endocrine function within the 'normal' group that we cannot make a direct approach toward correlating any hypothetical differences with differences in intelligence.

Endocrinopathies are of such frequent occurrence that an evaluation of intellectual changes in these cases is of considerable importance. It must be recognized that low intelligence is also of frequent occurrence and may be found associated with an endocrine dysfunction by chance alone. With complete loss of function of the thyroid gland or pituitary body the intellectual level is almost invariably low and can occasionally be improved by treatment. We have learned little about the association of the milder degrees of hypofunction of the thyroid gland and the pituitary body with low intelligence. Lawrence and Rowe (**16**) found that in a group of 100 patients who had hypothyroidism from which cretinism had been excluded only 6 per cent were retarded mentally. Rowe (**22**) found mental retardation in 6 per cent of 185 cases of dysfunction of the pituitary body, while only 1.6 per cent of a control group of 500 individuals having disorders which simulated endocrine dysfunction showed retardation. Fox (**10**) reported that the average IQ for 101 patients who had hypothyroidism was 75, with a range from 33 to 115. A group of twenty-three patients who had hypopituitarism had an average IQ of 74, with a range of 30 to 110. These averages seem significantly low until it is considered that the average IQ for the total 1867 heterogenous cases among which these endocrinopathies were found was only 78. It is certain that mental deficiency is associated with the mild degrees of hypofunction of the thyroid gland and the pituitary body more frequently than chance would allow. It is equally certain that large numbers of individuals who are intellectually normal are suffering from malfunction of the endocrine glands and also that many of the feeble-minded are free from any

detectable endocrine defect. It does not seem possible at present to indicate any narrow limits within which the true amount of association might be expected to fall.

Insofar as the gonads, suprarenal glands, pancreas, and parathyroid glands are concerned, there is little reason to assume any substantial relationship between their level of functional activity and the learning capacity of the individual. In a study of twenty-three Chinese eunuchs, McCartney (17) found them to be of good intelligence. In pubertas praecox there is precocious development of the sex glands but no acceleration in rate of mental development. Rowe (22) found no cases of mental retardation among 125 patients manifesting gonadal dysfunction and 15 patients who had pancreatic dysfunction.

Attempts to investigate the problem through the experimental alteration of internal secretion have been limited to the animal field. Most of the findings here are invalidated either on the basis of a small number of cases or through some serious error in technic. An exception is the excellent study of Commins (7) of the effects of castration on the learning ability of rats. Using experimental groups of 30 to 40 rats grouped according to castration at 25, 90, 130 and 170 days of age, their learning ability was compared to that of controls which had been subjected to false operations. Learning ability was measured by two elevated mazes, a multiple-T maze, and a light discrimination box. There was no significant difference between the performance of any two groups.

Emotion

The greatest interest which psychologists have shown in endocrine function is relative to the possible relationship between endocrine secretion and emotional experience. The classic experiments by Cannon, which demonstrated that widespread visceral changes take place during emotional reactions, were interpreted by many psychologists as fitting in perfectly with the James-Lange theory of emotion. Since it was demonstrated that epinephrine is discharged during emotion and that injection of epinephrine is followed by all

the visceral changes encountered in emotion, it was assumed that the following sequence occurred in the arousal of emotion: stimulus, epinephrine, visceral reactions, visceral sensations (emotion). Cannon (4) warned very early against an interpretation of his findings in the light of the James-Lange theory and has later (5) raised several objections to the theory which thus far have not been adequately answered.

Maranon (18) first reported attempts to produce emotional experience in human subjects by the injection of epinephrine. It was found that true emotion was seldom produced, although the subjects frequently reported bodily sensations recognized as accompanying fear. A few subjects did seem to experience a true emotion. These findings were essentially duplicated by Cantril and Hunt (6), by Landis and Hunt (15), and by Koppanyi (14). The instances in which epinephrine did seem to produce genuine emotion are by no means dependent upon the James-Lange theory for explanation. It is conceivable that sensations arising from visceral changes served as an adequate stimulus for the emotion, although not in themselves constituting the emotion. Cannon (5) has advanced considerable positive evidence which favors a thalamic theory of emotion. Those who hold to a prepotent rôle for epinephrine in causing emotion are placed in the position of having to support their views largely on the basis of faith as opposed to a large amount of contrary scientific evidence.

No hormone other than epinephrine has been seriously thought of as having a prepotent rôle in the immediate production of emotion. There is not any direct evidence to support the theory that differences in temperament, among normal individuals are the result of differences in endocrine make-up. Changes in the threshold of excitation of emotion and changes in intensity of emotion have been described in association with almost every known endocrine disorder. It seems highly probable that such changes do occur, but the kind of evidence offered in support is not thoroughly satisfactory. Reasons for a lack of quantitative evaluation in this field are not obscure. No measurable body change has ever

proved to be a reliable criterion of the subjective experience, which after all is what the word 'emotion' generally refers to. Nor can the verbal reports of the naive subject in the clinical situation be relied upon in reporting emotional changes.

Most cases of hyperthyroidism are characterized by varying degrees of nervousness and irritability. It is generally assumed that the nervous instability is a consequence of the hyperthyroidism. The nervous symptoms of exophthalmic goiter can be produced in normal animals and humans by the administration of thyroxin or thyroid substance. Typical cases of cretinism and myxedema are characterized by sluggishness and apathy. However, there is a variety of hypothyroidism in which the patient is extremely irritable and over-responsive. In a study of 100 cases of hypothyroidism, Lawrence and Rowe (16) found irritability to be a definite symptom in 30 cases.

Sexual Behavior

In mammals below the monkey on the phylogenetic scale the female becomes sexually receptive only during estrus. Since the appearance of estrus is an adequate criterion for the presence of the follicular hormone, this correlation between the presence of sex hormones and manifestation of sexual behavior in the female animal can be considered well established. In the male animal a similar relationship exists, but it is less definite. The testis secretes its hormone before puberty, but in smaller amounts than subsequently. Among the higher apes and human beings little is known of the relative importance of the various factors which play a part in the genesis of sexual behavior. Bingham (3) reported that young apes indulge in sexual practices before puberty and it is a matter of general information that the same is true of human beings.

The general effect of castration is established, but no universally applicable conclusion can be drawn regarding its effect on sexual behavior. Stone (26) castrated 42 male rats at 90 days of age and found that approximately two-thirds of the group continued to copulate as long as one month; 55

per cent for 2 months, 43 per cent for 3 months; 26 per cent for 4 months, 21 per cent for 5 months; 10 per cent for 6 months, while 8 months marked the limit. Similar results (**27**) were obtained with rabbits, although the duration of sexual behavior was not as long. Moore (**19**) noted that male guinea-pigs which had been castrated 30 days after birth have been employed for detecting heat periods in female animals. Since the male sex hormone is eliminated from the body a few days after castration, this prolongation of sexual activity would indicate that it is not completely dependent upon the presence of the hormone. In the female animal estrus is abolished by castration; consequently, sexual receptivity is invariably absent after this operation. The marked tendency for castration to reduce sexual desire still holds true for human beings although many exceptions must be admitted. McCartney (**17**) examined 23 Chinese eunuchs and reported that most of them frequently indulged in sexual intercourse as well as in homo-sexual practices. Many other instances in which capacity and desire for copulation survived castration have been reported. Likewise, there are cases in which women have retained their sexual desire after double oöphorectomy and after the menopause. Commins and Stone (**8**) pointed out that since a marked percentage (25) of married women do not experience sexual desire, it is necessary to check postoperative with preoperative reports regarding such desire. The diseases which make oöphorectomy necessary are likely to be serious; therefore, it would also be well to pay attention to the physical condition of the subject in attempts to evaluate the importance of ovarian hormones in maintaining sexual desire.

Motility

The development of simple and reliable methods for measuring voluntary activity in lower animals has made it possible to carry out quantitative studies of the relationship existing between endocrine function and this behavior trait. Similar studies are not available for humans although there is much casual description of motor behavior in the literature on diseases of the endocrine glands.

In rats there is a striking relationship between the level of activity and the estrus cycle of the female. Slonaker (25) and Wang (28), working independently, demonstrated that activity is increased markedly during estrus. The actual mechanism for this excitation of activity is unknown. High levels of activity are absent before sexual maturity, and are abolished during pregnancy, pseudo-pregnancy, and lactation. Removal of the gonads of either sex at any time of life is followed by a permanent low level of activity. The level of activity of the castrated animal of either sex may be increased by the injection of follicular hormone. Heller (11) investigated the possibility that individual differences in the activity of the normal male rat are dependent upon differences in the secretory activity of the testes. Inactive male rats were judged to possess a high concentration of testicular hormone, as indicated by the condition of the accessory glands of reproduction. Injection of 'heben' a substance which was extracted from the urine of pregnant women, and which was known to be a potent gonadal stimulant, failed to increase activity.

Removal of the thyroid gland in rats is followed by marked reduction in activity. Richter (21) found that this loss in activity could be corrected in part by feeding small amounts of thyroid extract. Attempts to raise the activity level of normal rats by feeding or injecting thyroid substance have uniformly failed. Parathyroidectomy was found by Durant (9) to depress activity only temporarily. Work on parathyroidectomy in rats is difficult to evaluate in the light of many conflicting statements in the literature regarding the occurrence of accessory parathyroid tissue.

Removal of all the suprarenal cortex invariably results in the death of the animal unless it receives substitution therapy. Consequently, it is not surprising or of special significance that total suprarenalectomy reduces voluntary activity. There is some reason to believe that the suprarenal medulla is dispensable insofar as activity is concerned. Bacq (2) performed abdominal sympathectomy and denervated the suprarenal medulla in 13 rats and found only a temporary

depression of activity level. Nice, Greenberg, and Greenberg (**20**), found that administration of adrenalin chloride to normal rats decreased their activity and that it was not effective in raising the activity level of suprarenalectomized rats.

Hypophysectomy reduces activity to a very low level. The anterior lobe of the pituitary body is known to have the function of stimulating the thyroid gland, gonads and suprarenal cortex. Removal of the pituitary body is probably equivalent to producing a state of hypofunction in each of these other organs. Atwell (**1**) has been able to increase the activity of hypophysectomized rats by injecting the hormone of the suprarenal cortex. Presumably, this had the effect of correcting a state of deficiency of the suprarenal cortex.

In the case of human beings such syndromes of endocrine hypofunction as cretinism, myxedema, pituitary cachexia, and Addison's disease almost always include reduced activity. The hypomotility is too obvious for question. With the more mild states of hypofunction of the thyroid gland, pituitary body, and suprarenal cortex, we may suppose that activity is also decreased, but a more accurate measure than casual observation is needed to establish this. Many patients who have exophthalmic goiter give the appearance of being overactive and exhibit many purposeless movements.

Abnormal Behavior

Many factors limit the investigator in attempting to establish relationships between glandular disorder and abnormal behavior. Both occur frequently and have some chance association. It is extremely difficult to make a correct diagnosis of endocrine dysfunction. Evaluations of abnormal behavior are equally difficult to make. Few individuals are free from personality traits which might readily be considered as abnormal. Factors of suggestibility influence both the subject and observer to such an extent that evaluations of improvement following endocrine therapy are likely to be unreliable.

Rowe and Pollock (**24**) have reported on the association

of psychoses and psychoneuroses with endocrine dysfunction. Among 4,000 patients who were referred for diagnosis, the ratio of patients having an endocrine disorder to those who were free from endocrine disorders was 3 to 2. In this total diagnostic group there were 250 patients who manifested either a psychosis or psychoneurosis. Among this 'mental' series the patients showing an associated endocrine dysfunction outnumbered those who had normal endocrine function by a ratio of 3 to 1. Another expression of this association is the finding that 8.1 per cent of the 2,308 patients who had endocrine dysfunction were also suffering from some mental disorder, while only 3.7 per cent of the patients who had normal endocrine function showed an associated mental disorder. Mental disturbances were present in 8.5 per cent of the 1,204 cases of pituitary dysfunction, in 5.2 per cent of the 592 cases of thyroid dysfunction, and 10.5 per cent of the 512 cases of ovarian dysfunction. These figures are still more significant when it is considered that many of those patients who were free from endocrine disorders did have lesions of the nervous system and other conditions which are considered causal of mental disease.

Hoskins and Sleeper (13) made a metabolic study of 80 cases of dementia praecox. Evidence of endocrine involvement was found in 50 per cent of these cases. There were 14 cases in which there was dysfunction of the thyroid gland, and 13 in which there was involvement of the pituitary body. Endocrinotherapy was employed in 53 cases. Improvement was noted in 18 of 37 cases in which there was endocrine dysfunction, while only 5 of the 36 patients who had normal endocrine function showed improvement. Hoskins reported the average metabolic rate for 214 patients who had dementia praecox to be 88.3 per cent of normal standard.

Rowe (23) has studied the association of endocrinopathies with behavior disorders among children who were less than seventeen years of age. Among 374 cases of endocrine dysfunction, behavior problems occurred in 18.2 per cent. In 276 cases in which the endocrine function was normal there were behavior problems in 13 per cent. Here again patients

who had normal endocrine function had neurologic conditions which were probably productive of behavior problems in themselves.

The number of papers concerned with endocrine factors and abnormal behavior is very large. Only a small minority of these studies have furthered our knowledge about the problem. The studies which have been treated in this discussion are among the best. It is very clear that deviations from normal personality are associated with endocrine disorders more frequently than chance will allow. Similarly, it is clear that the association is not inevitable and that either may occur without the other.

Comment

It is possible to take any point of view on the subject of endocrine influence on personality and select data which, if accepted at their face value, would support it. We have considered only a few personality traits and have discussed a small proportion of available studies. Admittedly, there is nothing to be said which will make my point of view universally acceptable.

Normal changes in personality, which correlate with age, are undoubtedly dependent upon the presence of endocrine glands just as they are dependent upon the presence of the heart, lungs, liver, and other vital organs. Those endocrine glands which are concerned with sexual maturation do seem to have some special rôle in initiating the changes in sexual behavior, which are seen at puberty. Many writers, probably as many psychologists as endocrinologists, have failed to make the discrimination between hypothesis and demonstrated fact in claiming and teaching that all somatic and psychologic differences have an endocrine basis. There is no really crucial evidence against this view, but it is more in keeping with the few known facts to regard the endocrine glands as concerned with the maintenance of homeostasis but to consider them normally lacking in prepotency for bringing about differences in personality.

Diseases of the endocrine glands, which materially alter

the secretory activity of the gland, are definitely associated with changes in personality. Similarly, the removal of an endocrine gland or the injection of physiologically active extracts of the gland are capable of altering behavior traits. The suprarenal medulla, the gonads, and the posterior lobe of the pituitary body are not essential to life and seem to be dispensable insofar as many physiologic functions are concerned. Interference with the normal secretory activity of the suprarenal cortex, the anterior lobe of the pituitary body, the thyroid gland, and the parathyroid glands, may have as either a direct or indirect effect an alteration in the metabolic processes of every tissue of the body. It is not surprising therefore that changes in personality follow any profound alteration in the amount of hormones secreted by these glands. The fact that changes in personality do not always accompany an endocrinopathy demands explanation. The tissue of the nervous system seems best protected against certain abnormal metabolic conditions and it is not unlikely that, in the more mild degrees of involvement of the endocrine glands, the nervous system is able to maintain a homeostasis for itself.

With endocrine disorders occurring frequently it is important that the personality status of these patients be evaluated. Likewise, the experimental work upon alteration of endocrine function is important as a check on changes thought to occur in disease. In addition, these investigations may throw some light on the hypothesis that variations in secretory activity of 'normal' endocrine glands are basic to individual differences in personality. If we find that individuals with mild but definite hypothyroidism are of average intelligence, it would be difficult to postulate that hypothyroidism, which was so mild as to escape detection by the clinician, could lower the intellectual level. If animals showing a low level of voluntary activity or of sex drive do not change in respect to these behavior traits when the gonads are stimulated to greater secretory activity, it is then difficult to explain individual differences in such traits as the result of differences in amount of sex hormones.

Problems in this field are likely to be only slightly ad-

vanced by those unfamiliar with the physiology of endocrine function. The secretory rate can be altered by the ablation of the gland and by the administration of glandular extracts. Only in gonadectomy can the novice be relied upon to remove all of the gland. For the other endocrine glands even the experienced experimenter on animals is forced to evaluate the results of his operation by some outside criterion. The presence of accessory tissue for most glands further complicates the problem. A partially ablated gland or a small amount of accessory tissue will rapidly compensate for its deficiency. To effect an increase in the amount of some hormones in the body is less simple than has been believed because the secretory activity of a gland may be suppressed by the administration of the active principle of that gland. It is very common to regard each endocrine organ as the sole physiologic source of the secretions produced by it. It has not been demonstrated that this generalization is strictly true for any endocrine body. Proper diagnosis of endocrine disorders of human beings is likewise far from simple. Desirable clinical material is likely to be available only in the larger medical centers.

Making available suitable material is only half the problem. The quantitative evaluation of behavior and personality traits is difficult and there is much justification for adding that a knowledge of psychology is just as essential a prerequisite as a knowledge of endocrinology for those who expect to advance the problems in this field. One must view with discouragement the growing tendency among those interested in personality measurement to accept uncritically the questionnaire tests of personality traits. Evidence to support claims for validity of such tests is not adequate in any instance. Admittedly to ignore these tests would leave the investigator without instrumentation for evaluating many of the personality traits which might interest him. No alternative can be suggested here other than to limit study to the few behavior and personality traits which are measurable by standardized methods.

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THE COMPARATIVE APPROACH TO PSYCHOLOGICAL PHENOMENA

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The great increase in experimental literature dealing with behavior of infrahuman organisms, both in laboratory and field situations, makes it advisable for the comparative psychologist to pause, at intervals, and survey the theoretical foundations of such investigation. Much useless experimentation and confused as well as questionable interpretation would be avoided if the investigator were as keenly aware of the general purpose and implicit postulates of experimentation as he usually is of details concerning apparatus and methodology. This is not an attempt to belittle the recent trend toward emphasis of experimental techniques, but rather a plea for equal and thorough consideration of the implications and general significance of the problem, prior to actual experimental investigation.

Comparative psychology involves the comparison of the psychological behavior of all living things. In this sense it is *general* or *evolutionary* psychology. All too frequently we rely for our psychological data upon the average white North American adult male or female specimen of *homo sapiens*, and all too frequently such data constitute the exclusive content of a course bearing the caption, 'elementary' or 'general' psychology. *Few of the 'general' statements made regarding psychological phenomena apply to infrahuman organisms or to human beings removed from our culture in space and time.* A glaring example of this very common practice is taken from the preface to a recent textbook of experimental psychology by Bills (1), who states:

> The title of this book, *General Experimental Psychology*, was chosen advisedly. The book aims to encompass a somewhat wider subject matter than has heretofore been included in experimental

textbooks . . . no attempt has been made to include all fields of psychology which have yielded large bodies of experimental data, but only those included within the term *general*, *i.e.*, adult, human, normal psychology. The field of Individual Differences has been arbitrarily excluded. Experiments in Animal and Abnormal Psychology have been introduced very sparingly. The emphasis throughout is on fundamental mechanisms.

It is now being widely recognized that some degree of so-called mental behavior is exhibited by every organism, no matter how simple or primitive, and that much benefit can be derived from separate study and mutual comparison of their behavior. This fact has often led, however, to the serious error of considering comparative or 'animal' psychology, as it is sometimes called, as a *field* of study, distinguished from and antithetical to an equally hypothetical 'field' of human psychology. This erroneous distinction is due in part to the traditional ecclesiastic man-beast dichotomy (*cf.* **11**, **12**, **16**), with its attendant lack of biological perspective, and in part to the inadequacy of techniques for studying many of the more complex processes in infrahuman organisms which has heretofore existed. This conception of comparative psychology as a 'field' of study is also objectionable on the grounds of misplaced emphasis. The animal forms utilized in comparative research are, strictly speaking, not the objects of ultimate interest, but only *differing loci of behavior interaction*. This 'behavioral' view of the primary datum of comparative psychology has been termed in the present paper the *behaviorocentric* point of view, and will be discussed in detail below.

The history and development of comparative psychology is too well known to be reviewed here (*cf.* **11**, **12**, **16**). Suffice it to say that the very right of existence of the science has often been questioned. Thus many mentalists, in their effort to preserve the traditional man-beast dichotomy, as well as to combat the objectivity of the growing comparative movement, have held that we can never know the animal mind, since our knowledge is only inferential in character. Many scientists, among them Claparède (**2**) and Morgan (**6**) have argued in behalf of comparative psychology, whereas

others, particularly Nuel (9), have opposed it, although without proof, by denying that human and animal psychology rest upon the same basis. Morgan was quick to point out, however, that such a distinction, even if justified, would not result in a human-infrahuman dichotomy, but rather in a distinction between that part of the human field wherein introspection can be utilized and that part, both human and infrahuman, wherein it cannot. He also added that the mental processes of the human infant, as well as those of many of the subnormal and insane, do not yield to introspective investigation, and must therefore be studied in much the same way as one would study an animal subject.

Contemporary work has shown, however, that the more subtle behavior problems can likewise be investigated in infrahuman subjects by utilizing recently developed experimental techniques. In fact, the process of human introspection itself appears to be a particular type of response, employing a verbal response-indicator, whereas the animal can be easily trained to use a manual or locomotor indicator of reaction, as some of the recent experimental work on sensory acuity and discrimination, learning, delayed reaction, multiple choice, and symbolism will testify. Nor need we assume, as did Verworn, that the greater the similarity between a given organism and man, the greater the validity of inferences regarding the mental life of the former.

Claparède's and Morgan's arguments have been further elaborated by Washburn (15). Having raised the question "as to whether comparative psychology is possible at all," she makes the following reply, which, although based on a faulty parallelism, nevertheless did much to refute the opposition.

> Must we accept the statement that no knowledge whatever of the animal mind is obtainable? If so, we must also admit that human psychology is impossible. Our acquaintance with the mind of animals rests upon the same basis as our acquaintance with the mind of our fellow-man; both are derived by inference from observed behavior. The actions of our fellow-men resemble our own, and we therefore infer in them like subjective states to ours: the

actions of animals resemble ours less completely, but the difference is one of degree, not of kind (p. 23).

It should be parenthetically mentioned that a far more pertinent and serious consideration in this respect relates to the morphology, particularly the dominant receptors and action-systems, of the animals studied. Since any response made by a given organism is conditioned in part by the action-system of that animal, it becomes necessary for the investigator at least partially to adapt the problem to the action-system of that organism. When such varied and diverse adaptations are made, however, the problems appear so dissimilar that the careful investigator hesitates in making inter-group comparisons. The same apparent paradox exists with regard to modality of stimulation and other problems in the sensory field. The only solution, so far as valid inter-comparisons are concerned, appears to be in the selection of problems and ways of stimulation best suited to all the forms to be studied, as well as in training and utilization of genetic control so as to minimize differentiation. It should be remembered also that certain general phenomena or patterns of behavior may be studied and found to exist regardless of the particular configuration of the protoplasmic matrix. Thus this seemingly intrinsic difficulty in the comparative method applies only in those cases where the interest is in the different organisms whose behavior is investigated ('organismo-centric' view; *cf.* below) rather than in the behavior phenomenon itself ('behavioro-centric' view; *cf.* below). In fact the presence of certain behavioral phenomena in animals of widely differing organization may prove most advantageous, since the phenomena can then be studied in their various manifestations, which is exactly what the student of a broader comparative psychology wishes to do.

We have considered the *inclusiveness* and extreme *breadth of scope* of the comparative approach. Little need be said with regard to its *objectivity*. Nowhere in the domain of psychological investigation has a more thorough-going naturalistic point of view, nor a more complete utilization of controlled experimental conditions, prevailed. The canon

of Morgan (5), among other developments, paved the way for a more and more objective approach to the study of organismic behavior. Watson's subsequent statements (17, 18), which denied at the outset any such philosophical distinctions as mind-body, subjective-objective, or conscious-unconscious, made for an even more realistic and internally consistent formulation of the subject matter of the science. The effects of such a point of view, originating in animal psychology, were soon evidenced in studies dealing with human material, for, as Warden (11) has pointed out, Watson's attack upon subjectivism in human psychology amounted to "an attempt to cast out egocentric interpretation from human psychology just as anthropomorphism was being forced out of the infra-human field by the objective principle." Warden and Warner (12) have elsewhere summarized this general objective trend in comparative psychology, with its naturalistic categories of organism, stimulus, or environment, and response, or behavior, and have maintained that "the proper goal of the objective comparative psychology is the determination of the conditions and laws of stimulation-response process, involved in the continuous interaction between the organism and its environment." Yerkes (20) has also pointed to the objective methodology of the discipline, with its "invention and refinement of methods of observation, perfecting of observational controls, increase in accuracy and completeness of description, and extension of influence," and has emphasized the significant influence, both methodologically and factually, which the science has exerted upon all branches of psychology, education, and the social sciences.

Morgan (5) was undoubtedly one of the first to realize the need for and possibilities of this comparative approach to psychology in general. He states:

> A distinguishing feature of modern psychology is the employment of the comparative method. So long as the psychologist restricts himself to the introspective study of the workings of his own consciousness, his conclusions rest on a basis which, however sure it may appear to himself, must be limited by the inevitable restrictions of his own individuality. When he compares and cor-

relates his own results with those of other introspective observers, he becomes so far a comparative psychologist, and by widening his basis renders his conclusions more comprehensive (p. 36).

Thorndike (10), in discussing the question, 'Why study animal psychology?,' has admirably stated that "man is a vertebrate, a mammal, and a primate, as well as *homo sapiens*." Hall (4) has also argued for the broadest comparative approach. After pointing to the wealth of data derived from students of animal behavior, as well as to the recognized applicability of many of these data to problems in human behavior, he continues:

> The proper study of psychologists is the behavior of organisms—whether these organisms be rats, cats, apes, or men . . . the similarity of behavior from amoeba to man argues against any breach between human and animal psychology. . . . An isolation between comparative and human psychology is unwarranted pragmatically as well as logically (pp. 2–3).

We have stated above that comparative psychology, in the broadest use of the term, may be called general or evolutionary psychology. Its province is the study, understanding, and formulation of the laws of organismic behavior, or stimulus-organism interaction, as evidenced now by the plant, now by the amoeba, and now by the anthropoid. In an address delivered at St. Louis in 1904 before the Congress of Arts and Sciences, Morgan (6) defined the province of comparative psychology as follows:

> The fundamental principle underlying and giving unity to these departments of study, in their genetic and strictly scientific aspect, is evolution . . . the province of comparative and genetic psychology, as I conceive it, is to investigate the nature and mode of development of mental processes, dealing with them in their synthetic rather than their analytic aspect, at any rate employing the methods of comparison and analysis with a predominantly synthetic aim and in such wise as to enable us to reach general principles which may be applied to the elucidation of particular cases (p. 78).

This additional emphasis upon the *ontogenetic* or *developmental* aspect of behavior, as well as upon the *phylogenetic* or *evolu-*

tionary aspect, is a characteristic feature of the comparative method. As in the related sciences of comparative morphology and physiology, the behavior of present forms can be considered as *diversifications of homologous behavior* in ancestral forms (*i.e.*, 'living fossil' behavior), thereby permitting at least scientific speculation concerning the evolution of organismic behavior. Yerkes (**20**) has stated the need for comparative study of the development of behavior in the individual and evolution of behavior in the species. Warden, Jenkins, and Warner (**13, 14**) have also stressed the biological approach, based upon the fundamental concept of organism-in-environment.

In a previous connection (**3**), the writer has briefly set forth three general but distinct points of view or approaches to comparative psychology. These are here presented and elaborated, and serve as a logical and serviceable classification of the various opinions which must be differentiated. For purposes of convenience, we shall call these the anthropo-centric, organismo-centric, and behavioro-centric points of view, respectively.

1. *The Anthropo-centric Point of View*

The first or 'anthropo-centric' view, as its name implies, makes *man* the center of reference and ultimate interest. According to this approach, all material gathered in the animal field is valuable only in so far as it contributes to the understanding of human behavior. This was formerly the most prevalent attitude, often being set forth as a 'justification' for the study of behavior in infrahuman forms, and such statements have by no means disappeared today. Among the exponents of this point of view, historically, were those who discounted the possibility of a comparative approach including both man and animal within its sphere of investigation, and those for whom the pure science point of view had not displaced the concept of the primacy of applied science.

2. *The Organismo-centric Point of View*

A second and broader view places the interest in each organism *per se*, regardless of its position on the phyletic

scale. Thus exponents of this approach emphatically declare that comparative psychology is not a mere adjunct to human psychology, but is intrinsically interesting, and hence cannot be dominated by a single species. Although working almost exclusively with human subjects, Wundt (19), as early as 1894, recognized the right of comparative psychology to develop a content independent of human reference. This change in point of view is not characteristic of psychology alone, but may also be illustrated in the field of biology. Thus the Darwinian movement, originally judged for the bearing it had upon the origin and description of the genus *homo*, soon led to the accumulation of such a mass of evidence from infrahuman organisms that man ceased to be the center of reference. Thus, according to this view, the main task of comparative psychology becomes one of cataloguing behavior items or details, and the behavior of each form is isolated for separate study, with the view to an ultimate description of the behavior repertoires of all known organisms. This organismo-centric point of view is widely current among many contemporary comparative psychologists who have adopted a strictly biological attitude, and who attempt systematically to collect data on various animal forms in order to compare such forms both as to morphology and behavior. The primary interest is in each organism so studied, and the behavior which it exhibits is used only to differentiate it from similar and more widely contrasting forms (*cf.* 13, 14).

3. *The Behavioro-centric Point of View*

Many psychologists, in their attempt to counteract the anthropocentric tendency, have merely collected facts and isolated details, and appear to have been entirely oblivious to the implications and relative importance of their data. Likewise the investigator too frequently becomes so immersed in a study of a given animal that he loses the psychological perspective, and becomes more interested in a comparison of the various *forms* studied than in a comparison of the *behavior* of those forms. Thus a third possible approach to comparative psychology is one in which the emphasis is

placed not on mere man and his behavior ('anthropo-centric' point of view), nor on the discrete behavioral data obtained from the various organisms at various phyletic stages ('organismo-centric' point of view), but rather on the *behavior phenomenon* itself. The fact that such phenomena, *wherever found*, exhibit a *common* pattern, sequence, or functional characteristic, is here taken as the fundamental and unifying principle. The problem then becomes one of studying this pattern, and describing its characteristics, conditions, and loci of incidence, thereby bringing all possible techniques to bear upon the study of 'mind' in its most diverse and yet inclusive aspects.

Thus comparative psychology, as a strictly scientific psychological discipline, has had to wage internal battles against the anthropo-centric view on the one hand, and against what we have termed the organismo-centric view on the other. The organismo-centric view, has had its chief value in counteracting the teachings of the opposite or anthropo-centric view. Watson (17) has stated, for example, that just as the biological studies on race differentiation and inheritance in amoebae form a separate division of study to be evaluated in terms of the laws found there, so must the laws of behavior in amoebae be determined and evaluated in and for themselves, regardless of their generality or bearing upon such laws in other forms. Exclusive concentration on a given animal form, however, will not only lead to a narrow, limited, and frequently biased outlook, but may frequently result in questionable generalizations, as is illustrated by the following quotation from Munn (8). After pointing out that more is known about the albino rat than about any other infrahuman animal and that the rat is "the standard animal for investigation of many fundamental psychological problems," Munn continues:

> The present treatise demonstrates that it is possible to write an essentially complete outline of the science of animal behavior without going beyond the available data on the rat (preface, p. v).

We have reviewed briefly the various implications of the comparative approach to psychological phenomena. It has

been the thesis of the present paper that the most fruitful approach, as well as the one most in harmony with the maintenance of psychology as a strictly independent scientific discipline, is that which places the emphasis for study not upon man and his behavior (anthropo-centric point of view), nor upon the different animal forms and discrete behavioral data obtained in organisms of differing phyletic status (organismo-centric point of view), but rather upon the behavior phenomena themselves, exhibited by all organisms including man (behavioro-centric point of view).

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